Final Report

Accessible Home Vital Signs Monitoring System

by

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Abstract

The Accessible Home Vital Signs Monitoring System is a project funded by the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation's (RERC-AMI) National Student Design Competition. This device has been designed to be accessible for clients of different abilities and ages. The Accessible Home Vital Signs Monitoring System that we have designed measures blood pressure, blood oxygen saturation, heart rate, temperature, weight, and respiration rate. In this system, these vital signs are displayed on a monitor and saved to a USB flashdrive. Through a secure website that is part of the system, the client can upload their vital signs from the flashdrive via any Internet connected computer. This allows clients to communicate their health status to physicians and healthcare providers anywhere in the world.

Accessibility is provided through large, well-lit LCD screens, a speaker system, and Braille customized buttons. Vital signs are displayed on large LCD screens, as well as spoken through a speaker system. An included alarm system to alert the client of abnormal vital signs uses both visual (lights) and auditory (sound) cues. A simple 3-button design provides an easy-to-use user interface, appropriate for all age levels and technological savvy. Also, all buttons are customized with Braille or Universal Symbols for the vision-impaired. The monitor includes rechargeable back-up batteries in case of power-failure, or if the client just does not to be homebound by their health monitoring needs.

1 Introduction

To fully understand this project and its drive, certain background information is necessary. This section explains the purpose of our design and our client. Also to give an understanding of the technology, this section contains information on vital signs monitors and similar devices that monitor health and wellness.

1.1 Background

With the aging baby boomer population, home health care is a growing and changing industry. The advent of telemedicine and advanced communications technology has allowed patient monitoring to move from the hospital to the home. By monitoring patients' statuses remotely, health care facilities can free up hospital beds and doctors' time for more critical patients. An integral part of remotely monitoring a patient's condition is the vital signs monitor.

There are many clients who are in need of an accessible home vital signs monitoring system. To make this device as accessible as possible, we have to address the many needs of our clients. An overview of these needs can be seen in three of our clients: Mat, Sani, and Dolores. Mat is a 52-year-old male in good physical condition. He is blind and works as a radio commentator. Mat just had a small stroke, and his doctor wants to monitor his vital signs from home for the next 90 days. Mat does not like devices that are very technologically advanced, but lives with his vision-impaired wife who loves the internet. Sani is a 31-year-old female who recently experienced a head

injury from an automobile accident. This accident left the right side of her body paralyzed (her dominant side). Sani is a lawyer and is now working part time from home. She must sleep in a hospital bed, and she administers pain medication to herself using an infusion pump. Her doctor monitors her vital signs by a computer system that is installed in her home. Sani does not want to appear sick to her family and friends. She would like a vital signs monitoring device that blends in with the other furniture in her home. Our last client is Dolores. She is an 86-year-old female who lives with her son, his wife, and their son. Dolores is deaf and has severe arthritis. She also has heart problems that cause her to receive infusions at home. These infusions are normally administered by one of her family members. Dolores' grandson Tyler is 11 years old, and he likes all kinds of electrical gadgets. He loves to help his grandmother collect her vital signs and send them to her doctors on the computer.

1.2 Purpose of the Project

The purpose of this project is to create an accessible home vital signs monitoring system. Although there are already similar devices on the market, it is our goal to design a monitoring system that meets our clients' specific needs. This device will improve our clients' quality of life by allowing health care professionals to monitor them from home, rather than from a bed in a hospital or nursing home. Our clients want to maintain their health, not appear sick to their friends, and continue to live with their families. The device we design will allow them to do these things. It will be accessible to the vision and hearing impaired, and it will be cost effective. Most systems available today are very expensive, and our purpose is to make an affordable device that is also accessible and easy to use.

1.3 Previous Work Done by Others

1.3.1 Products

Previous work on home vital signs monitors can be seen in the current models that are in hospitals and homes. There are many different types and brands of vital signs monitors available today. They range in size, function, and price. Most are very expensive, costing patients or healthcare providers upwards of $2,500 per system. Below are the descriptions of a few select monitors.

The monitor shown below (Fig.1) is the Welch Allyn Vital Signs Monitor.

Figure 1. Welch Allyn Vital Signs Monitor 300 Series

This device is small and lightweight. It is 6.6 inches tall, 10 inches wide, has a depth of 6 inches, and weighs 5.4 pounds. Some of its features include: an easy to read LCD screen, blood pressure monitor, built in memory for up to 99 sets of measurement data, thermometer, pulse measurement, blood oxygen level measurement, and a printer for record keeping. This device also comes with an optional wheeled stand making for easy transportation. The Welch Allyn system has an alarm that will go off if patients forget to take their vital signs at the specified time. With all of the above features, the Welch Allyn Monitoring system is approximately $3000.

The Philips SureSigns VS1 Vital Sign Monitor includes non-invasive blood pressure (NIBP) and pulse rate measurement systems. It weighs 8 pounds and is 9.3 inches tall, 9.4 inches wide, and 9.8 inches deep (Fig. 2). It can store up to 400 sets of vital signs and has a battery life of 6 hours. A bright LCD display displays the latest vital signs readings, and a backlit screen displays historical trend information. With these features and to monitor only two vital signs, this device costs approximately $2000.

Figure 2. DRE Philips SureSigns VS1 Vital Sign Monitor

Both the Philips and Welch Allyn monitors lack audio output and obvious buttons. Though both have internal memory, neither have the option to save vital signs off of the monitor.

1.3.2 Patent Search Results

There are many different types of vital signs monitors, so many patents of vital signs monitors exist. One such patent is a blood pressure and heart rate monitoring method and apparatus by Hewitt (U.S. patent number 4,967,756**)**. This system uses an auscultatory transducer and a microprocessor-based circuit to record blood pressure and heart rate. It also uses a new method to measure blood pressure without unnecessary constriction of the patient’s limb.

U.S. patent number 5,613,495 by Mills, et al. is for a high functional density cardiac monitoring system for captured windowed ECG data. It is a very small device that is lightweight and worn on the wrist. It uses dry skin electrodes that come in contact with the patient’s skin to take readings. This device also includes a speaker and method for transmitting the recordings over a phone line.

U.S. patent number 5,553,609 by Chen, et al. is an intelligent remote visual monitoring system for home health care service. This device is a way for a health care

professional to monitor a patient in their home from a remote location. This is done through normal telephone lines and uses two main databases for storing and sending information.

Finally, a vital sign remote monitoring device patented by Money, et al. (U.S. patent number 5,919,141) describes a device for the remote monitoring of a hospitalized patient's vital signs. This device provides interfaces for pulse oximetry, ECG, respiration, temperature, and blood pressure transducers. Readings are sent by a RF transmitter to a remote monitoring station.

1.4 Map for the Rest of the Report

The remainder of the final report covers design, budget, and other engineering considerations. The next section details the design process by discussing the three alternative designs and the optimal design of the accessible home vital signs monitoring system. The alternative designs show the changes that our vital signs monitoring system went through on its way to the final design, the optimal design. Following this section are the realistic constraints, safety issues, and impact of engineering solutions. The realistic constraints and safety issues were factors that had to be kept in mind when designing our device. The impact of engineering solutions section describes how our design affects different areas in society, including the environment, the economy, and the global stage. Next discussed is life-long learning and how our device and its design has contributed to our life-long learning. The report concludes with a timeline for the construction of our device, our budget, and each team member's contribution to the report and design of the device. Acknowledgements, references, and an appendix containing updated device specifications are also included.

2 Project Design

Engineering design is a process that involves research and revision. This section contains the three design alternatives created for our accessible home vital signs monitoring system, and the optimal design that was chosen. In each design section, any changes made are discussed, followed by an explanation of each subunit of the design. The optimal design was chosen because it keeps costs down while still being an effective home vital signs monitoring system. It is also the design that is safest, will last the longest, and be the easiest to manufacture.

2.1 Design Alternatives

2.1.1 Design 1

2.1.1.1 Objective

Our accessible home vital signs monitoring system will have the capability to non-invasively gather the client's heart rate, blood pressure, blood oxygen saturation level, and body temperature, and then send this data to their healthcare provider. The

data will be sent via a USB flash drive to a password-protected, encrypted website. This accessible home vital signs monitoring system design is an accurate and consistent way to obtain a patient's vital signs, regardless of the caregiver's skill level. The buttons on the front panel of the monitor will be large and printed with either Braille or a universal symbol, allowing patients who are vision-impaired or who have arthritis to successfully operate the monitor. Also to accommodate vision-impaired clients, a text-to-speech function will be implemented to allow the monitor to audibly communicate current vital signs readings. In addition, four bright LCD screens with wide viewing angles will be used to display the patients' vital signs. A visual and audio alarm will be installed to alert clients if their vital signs are abnormal. To collect the data, medical transducers will be commercially purchased and integrated into the accessible vital signs monitoring system. The items to be purchased are a finger pulse oximeter probe, an oral temperature probe, and an automatic blood pressure cuff.

2.1.1.2 Thermometer

To measure body temperature, a thermistor circuit will be used. The thermistor will be in the form of a commercially purchased, oral temperature probe (brand to be determined). It will convert changes in temperature to changes in voltage. Thermistors are inherently nonlinear, so to linearize the output of the thermistor, it will be placed in series with a resistor [9]. The value of the resistor will be determined from the resistance of the thermistor at room temperature and data from the temperature probe spec. sheet. For our use as an oral temperature probe, the thermistor needs to be linearized for temperatures from 90-104° F (32-40°C). After being linearized, the signal will be sent to a low-pass filter to filter out any noise and then passed to a non-inverting amplifier to be amplified. Finally, the signal will be sent to the microprocessor where it will be analyzed and passed to a LCD screen to be displayed.

2.1.1.3 Pulse Oximeter

To measure blood oxygen saturation, a pulse oximeter will be used. Pulse oximetry uses the optical properties of blood to determine blood oxygen saturation. Our pulse oximeter will have two parts: a finger probe and the oximeter circuitry. The finger probe for the pulse oximeter will be commercially purchased (brand to be determined). It will contain two LEDs, one that works at a red wavelength and the other at a near-infrared (NIR) wavelength. Also, in the probe will be a photodetector that will detect the light transmitted through the finger [16].

A non-inverting op amp combined with a FET will be used to create a constant current source to drive the LEDs. Two 555 timer circuits will be used to control the timing of the pulsing of the LEDs. An n-channel enhancement-mode MOSFET connected across the each LED will be used to pulse the output from them.

In the receiving end of the circuit is the photodetector. The photodetector used in pulse oximetry probes is a photodiode. The photodiode detects the light transmitted through the finger as current [16]. An op-amp configured for current-to-voltage conversion will convert the photodiode-detected current to voltage. Sample-and-hold circuits are needed (due to the pulse LED light) to reconstitute the waveforms at each of

the two wavelengths. The timing circuits that were used to control the red and NIR LED drivers also are used to provide the control pulses for their corresponding sample-and-hold circuits [16]. A simple sample-and-hold circuit can be created from a FET switch, capacitor, and op amp.

Once the signal goes through the sample-and-hold circuit, it is sent through a band pass filter to eliminate noise, then amplified and sent through an A/D converter and the microprocessor to be analyzed. A lookup table stored in the microprocessor will be used to calculate SpO_2 values. This signal is also sent through a low pass filter to extract the d.c. value of the transmitted signal, which is then sent to an automatic gain control circuit. The gain control circuit adjusts the light intensity from the LEDs so that the d.c. level always remains at the same value, whatever the thickness of the patient's skin, tissue, etc. This circuit is implemented by feeding the d.c. signal to one input of a differential amplifier. The other input to the amplifier is a constant reference voltage. The output of the differential amplifier, the voltage difference between the two inputs, is used to generate the voltage that sets the value of the LED currents [16].

Heart Rate

Pulse oximetry will also be used to determine heart rate. There are pulsatile signals detected in the intensity of the detected light by the photodiode. These pulses can be counted within a given time period to determine heart rate. This will be done by the microprocessor and displayed on an LCD screen.

2.1.1.4 Non Invasive Blood Pressure

One way in which blood pressure can be measured non-invasively is through use of an occlusive cuff. Automated blood pressure measurement includes two systems: the cuff control system and the microphone system to measure the Korotkoff sounds generated. The cuff control system involves inflating the cuff then deflating it at a slow rate to produce the Korotkoff sounds. A complex circuit is used to detect the Korotkoff sounds. The circuit must differentiate between the Korotkoff sounds, background noise, and the heart beating. It also must determine which phase a sound implies [15].

To measure blood pressure, an automated system will be used that measures Korotkoff sounds. Due to the complexity of the automated system, a commercially available system, such as the Omcron Automatic Blood Pressure Monitor, will be purchased and integrated in our vital signs monitor. The resulting measurement for blood pressure will be displayed on an LCD screen on the front of the vital signs monitor.

2.1.1.5 Processing, Display, and Alarm

To process the data, we will use the Microchip PIC16877F microprocessor. After the data has been processed the information will be sent to 4 different areas: the LCD displays, the speech module, the speaker, and alarm. For the LCD displays, 4 displays from Crystal Fontz will be used. Each display measures 80mm x 36mm with a viewing area of 66mm x 16mm, and a character height of 6.56mm.

To produce the speech we will use the Magnevation SpeakJet IC. It is an 18 pin IC that uses a mathematical sound algorithm to control an internal five channel sound synthesizer to produce sound. The SpeakJet can be controlled by a single I/O line from our PIC16877F Microcontroller [13]. Since this microchip requires phonetics and not text, the TTS256 Text to Code IC will have to be used in conjunction with the SpeakJet. The TTS256 is an 8-bit microprocessor programmed with letter-to-sound rules. This built-in algorithm allows for the automatic real-time translation of English ASCII characters into allophone addresses compatible with the Magnevation SpeakJet Speech Synthesizer IC. This IC is Compatible with Basic Stamp, OOPic, PIC and any processor with a serial port, like our microchip [13]. To play these sounds, a commercial speaker will be purchased. For our purposes, we chose a simple, small, .5W, 8 Ohm speaker to generate all our speech sounds, as well as the alarm. The alarm will include audio and visual features that will activate when the patient's vital signs become abnormal.

2.1.1.6 USB Device and Secure Website

Vital signs readings will be stored via a USB flashdrive. This device will then be connected to a computer in which it is possible to send the readings to any computer that has an Internet connection. The USB device that we decided to use is the Philips PDIUSBD11. This device uses I2C technology to connect to the microprocessor. This allows for easy communication between the two. By writing a computer program in the microprocessor, we will be able to send the data received by the machine to the USB device and then to the computer.

After the patient's vital signs have been gathered and recorded, they need to be sent to the primary healthcare provider. We will create an encrypted, password protected website to which the patient can upload the information from their USB stick. To ensure that the website is secure, HTML encryption software will be used to encrypt the contents of the website, allowing only those with the correct username and password to access it. We will use encryption software such as TagsLock Pro v 2.22 to hide the source code of our HTML documents. In order to use this encryption software, a website using the UCONN Biomedical Engineering server will be created.

2.1.1.7 Power Supply

When designing this project we found it rather important to include two different types of power. The device will mainly be run from an external power source by using a power cord. It will also be equipped with rechargeable backup batteries in case of a power failure. For the power supply we plan on using a very generic universal power cord, which will plug into the back of our device and then also plug into the wall. For the backup power supply we determined the best way would be to use nickel cadmium rechargeable batteries. Although lead acid batteries can sometimes produce more voltage, nickel cadmium batteries are safer and will recharge a lot quicker. The need for a backup battery is so the patient can take signs even if the power is gone.

2.1.2 Design 2

2.1.2.1 Objective

As with Design 1, our accessible home vital signs monitoring system will have the capability to non-invasively gather a client's vital signs and transmit them to their healthcare provider. To accommodate all users, the monitoring system was designed to be as simple and user friendly as possible. The following design differs from the first design in a few important ways. First, this new design is for a vital signs monitor that will measure 6 different vital signs. Our last design only measured 4 vital signs (heart rate, blood oxygen saturation, blood pressure, and temperature), but this design adds the equipment to measure weight and respiratory rate.

The thermometer linearizing circuit has been changed from a resistor to a Wheatstone bridge, which is more common in medical instrumentation and reduces heat created by the circuit itself. Instead of purchasing an automated noninvasive blood pressure monitor and incorporating it into our device, this report includes a design for an automated blood pressure system that will be part of the system itself. Finally, in this design we are using a Blackfin microprocessor instead of a PIC 16F877. The Blackfin was chosen for its superior processing capabilities and its ability to be programmed through LabVIEW™.

2.1.2.2 Thermometer

As with Design 1, a thermistor circuit will be used to measure body temperature. The thermistor will be in the form of a commercially purchased, oral temperature probe. The probe we have chosen for this is the Welch-Allyn # 02893-000 Sure Temp 690 Oral Probe from DREMed.com for a cost of $74.00, before shipping and tax. Unlike our first design (where the thermistor was linearized by a resistor), the thermistor will be linearized through the use of a Wheatstone bridge:

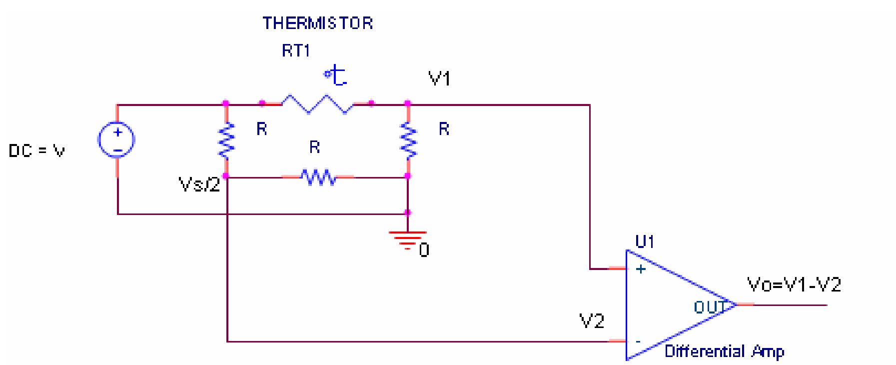


Figure 3. Thermistor Linearizing Circuit

For our use as an oral temperature probe, the thermistor needs to be linearized (calibrated) around 98.6° F (37°C), for a temperature range of at least 90-104° F (32-40°C). After being linearized, the signal will be sent to a low-pass filter to remove any noise. The signal will be sent to a non-inverting amplifier to be amplified and then

passed to the microprocessor where it will be analyzed and sent to an LCD screen to be displayed.

The thermometer will be tested by placing the probe in a beaker of water heated to a certain temperature and comparing the resulting temperature given by the thermometer to the actual temperature of the water. Final testing will be done by taking group members' temperature with the thermometer and comparing the reading with that taken by a commercial digital thermometer.

2.1.2.3 Pulse Oximeter

To measure blood oxygen saturation, a pulse oximeter will be used. The pulse oximeter finger probe that we will use is the DRE Datascope compatible SpO2 finger probe for $165.00 (price before shipping and tax) from DREMed.com. It contains two LEDs, one that works at a red wavelength and the other at a near-infrared (NIR) wavelength. Also, in the probe is a photodetector that will detect the light transmitted through the finger [16]. Like in Design 1, to transmit light, the LEDs need to be driven by a constant current source. This can be done by a non-inverting op amp combined with a FET. To control the pulsing of the LEDs, two 555 timers will supply 50μs pulses to the LEDs at a rate of 1 kHz. Finally, an n-channel enhancement-mode MOSFET connected across the each LED is used to pulse the output from them.

In the receiving end of the circuit is the photodetector. The photodiode detects the light transmitted through the finger as current [16]. The current is converted to voltage by an op-amp configured for current-to-voltage conversion. Because the LED light is pulsed, sample-and-hold circuits are needed to reconstitute the waveforms at each of the two wavelengths. The timing circuits that were used to control the red and NIR LED drivers also are used to provide the control pulses for their corresponding sample-and-hold circuits [16]. A simple sample-and-hold circuit can be created from a FET switch, capacitor, and op amp.

Once the signal goes through the sample-and-hold circuit, it is sent through a band pass filter with cutoff frequencies .5Hz and 5Hz to eliminate high frequency noise and the d.c. offset. Then, it is amplified and sent through an A/D converter and the microprocessor to be analyzed. A lookup table stored in the microprocessor will be used to calculate SpO_2 values. This signal is also sent through a low pass filter to extract the d.c. value of the transmitted signal, which is then sent to an automatic gain control circuit (the same as in Design 1). The gain control circuit adjusts the light intensity from the LEDs so that the d.c. level always remains at the same value, whatever the thickness of the patient's skin, tissue, etc [16].

Calibration of the pulse oximeter will be done through the lookup table stored on the microprocessor. Because we are using a Datascope compatible probe, we will obtain and load Datascope's lookup table onto our microprocessor. The pulse oximeter will be tested through a pulse oximeter simulator, a device designed to test the accuracy of pulse oximeters. We plan to find a simulator to use at a local hospital or the UConn Health Center.

Heart Rate

Pulse oximetry will also be used to determine heart rate, as in Design 1. There are pulsatile signals detected in the intensity of the detected light by the photodiode. One pulse is one cardiac cycle. The microprocessor will count the pulses to determine heart rate (beats per minute), which will be displayed on an LCD screen.

2.1.2.4 Non Invasive Blood Pressure

In this design, we will incorporate our own automated non-invasive blood pressure cuff into the system. Blood pressure will be automatically measured through the oscillometric method [15]. This is done by wrapping a blood pressure cuff around the upper arm and inflating it until the pressure around the arm due to the cuff collapses (or occludes) the brachial artery. The cuff is then slowly deflated. As the cuff deflates, blood starts pumping through the brachial artery causing minute vibrations of .5 to 1 mmHg in the cuff [4]. The pressure at which these vibrations start is the systolic pressure, and the pressure at which they stop is the diastolic pressure [5]. The block diagram in Fig. 4 illustrates how this method will be used to measure blood pressure in the accessible vital signs monitoring system. Each system in the flow chart is described in more detail in the following paragraphs.

When the blood pressure "Start" button on the vital signs monitor is pressed, the blood pressure cuff will be inflated to about 40mmHg above normal (160mmHg). The blood pressure cuff used will be a DRE Adult single lumen cuff from DREMed.com at a cost of $37.00, before shipping and tax.

The cuff will be inflated by a Sensidyne AA Series Micro Air Pump. A microprocessor, second to the microprocessor controlling the rest of the device, will control the inflation of the cuff. The sensor used to sense cuff pressure will be the NPC-1210 low-pressure sensor from GE. Once the pressure sensor determines that the cuff has been inflated to 160mmHg, the cuff will deflate slowly at a rate of 2-3mmHg/sec. Deflation will occur through a release valve (brand to be determined).

As blood begins flowing through the brachial artery again, it will cause small pulsations that will be picked up by the pressure sensor in the cuff. This waveform will be analyzed by the microprocessor to determine the systolic and diastolic pressures. A threshold voltage level will be set. This will be done by experimentally comparing blood pressure readings from a sphygmometer or other commercial device to those detected by our pressure sensor. Once 4 pulsations peak above the threshold level, the voltage will be recorded and from that value the systolic pressure determined. The microprocessor will continue to monitor the blood pressure readings and diastolic pressure will be taken when the voltage drops below the threshold voltage for 2 pulsations. After the diastolic pressure is determined, a command from the microprocessor will deflate the cuff quickly and completely.

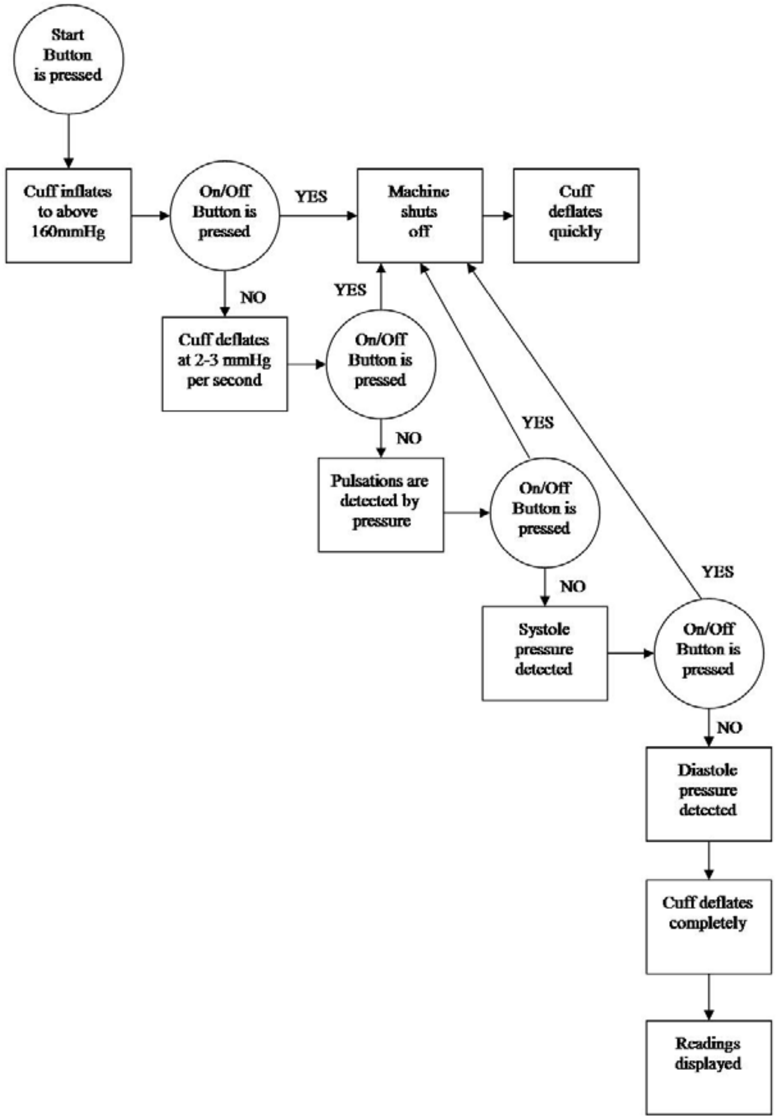


Figure 4. Block Diagram of Automatic Blood Pressure Measuring System

Due to the safety issues that arise with automatic blood pressure systems, we have incorporated a "kill switch" into our design (Fig 16) [18]. If at any time during the blood pressure measurement the user wants to stop the inflation of the cuff and rapidly deflate it, they just need to press the vital signs monitor "On/Off" button. This will cut power to the whole device and open the pressure release valve.

As stated previously, the automated blood pressure system will be calibrated experimentally. This will be done through establishing a threshold voltage by which correct pressure measurements for systolic and diastolic pressures can be made. Final testing of the device will be done by comparing its blood pressure readings to those of a sphygmometer. Finally, the rapid cuff deflation will be tested by experimentation (turning the vital signs monitor off during use).

2.1.2.5 Respiratory Rate

In this second design, we have incorporated the measurement of respiratory rate. To do this, the MLT1132 Piezo Respiratory Belt Transducer from AD Instruments will be used. Using a piezoelectric sensor placed between two strips, this belt measures the changes in thoracic or abdominal circumference due to respiration inhalation and exhalation. By stretching the elastic due to respiration, strain is placed on the sensor, which generates a voltage. This voltage is then sent through the transducer and converted into digital signals to be processed by the Blackfin. In plotting the voltage sent from the transducer, we can count each breath as a peak on the graph which corresponds to the maximum distance the belt traveled for that breath.

To test the accuracy of this transducer, we will compare our results obtained from using this respiratory belt to the results obtained the BioPac software. Calibrating the respiratory belt can be done by knowing the voltage of the piezoelectric sensors at rest. Ideally, there should zero voltage because there is no stress on the sensors. If the sensors do exhibit some voltage, the device will be zeroed at that corresponding voltage reading.

2.1.2.6 Weight

Measuring patient weight has also been included in this second design. This will be done by purchasing a commercially available digital scale and incorporating it into our device. The scale that will be used is the Homedics SC-200 Digital Scale ($24.95 at wholesalepoint.com). We will to build handles onto the scale to offer better support and safety to our clients with mobility problems. To connect the scale to our device, we will take apart the scale and break the connection between the circuit and its digital display. Then we will connect the scale output to our microprocessor, to be saved and sent to an LCD screen. The scale will already have been calibrated and tested by its manufacturer. We will do additional testing by comparing known weight values (dumbbells) to the values displayed by the scale when we place the weights on it.

2.1.2.7 Processing, Display, and Alarm

In this design, the microprocessor we have chosen to use is the Blackfin ADSP-BF535P Digital Signal Processor by Analog Devices. This processor is extremely versatile due to the fact that it can function as both a microcontroller and a DSP (Digital Signal Processor), allowing for either 100% DSP, 100% microcontroller, or a combination of the two [8]. This makes the Blackfin ideal for our design due to the fact that we are going to input and output the data like a microcontroller, but use the digital signal processing features to analyze and filter the signals (FIR and IIR filters). Like the PIC microcontrollers, the Blackfin contains an internal analog to digital converter. Using DSP, one can more easily design and modify their work due to the fact that it is all computer based. DSPs are also much faster than microcontrollers. A typical PIC microcontroller has a clock speed of about 20 MHz, whereas the Blackfin has a clock speed of 350 MHz. We will use the PF pins (I/O ports on microcontrollers) on the Blackfin to function as inputs for the transducers and outputs for the LCD screens and speaker. Due to the Blackfin's abilities, it should be the only microprocessor we need for

our device. The Blackfin can take C/C++ code as well as LabVIEW Vi's. Since we have had more experience using LabVIEW, we feel that LabVIEW would be a more suitable code to program the processor.

After the data has been processed the information will be sent to 4 different areas: the LCD displays, the speech module, the speaker, and alarm. For the LCD displays, 4 displays from Crystal Fontz will be used. These displays differ from our previous design due to the fact that they are a little larger, making reading the displays easier for the patients. Each display measures 122mm x 44mm, with a viewing area of 99mm x 24mm, and a character height of 8.06mm.

The same system as used in Design 1 will be used in this design to produce the audio output, the Magnevation SpeakJet IC. The SpeakJet will be controlled by a single I/O line from the Blackfin [13]. The TTS256 Text to Code IC will be used in conjunction with the SpeakJet. The TTS256 is an 8-bit microprocessor programmed with letter-to-sound rules. This built-in algorithm allows for the automatic real-time translation of English ASCII characters into allophone addresses compatible with the Magnevation SpeakJet Speech Synthesizer IC. The commercial speaker we have chosen to play these sounds is a simple, small, .5W, 8 Ohm speaker, which will also act as part of the alarm. The alarm will include audio and visual features that will turn on when the patient's vital signs become abnormal.

2.1.2.8 USB Device and Secure Website

Vital signs readings will be stored via a USB flashdrive, through the same system describe in Design 1. The USB device that we decided to use is the Philips PDIUSBD11. By writing a computer program in the microprocessor, we will be able to send the data received by the machine to the USB device and then to the computer.

After the patient's vital signs have been gathered and recorded, they need to be sent to their primary healthcare provider. To maximize patient privacy we have devised a way to securely transmit the patients' health information, minimizing the risk of interception. We will create an encrypted, password protected website to which the patient uploads the information from their USB stick. To ensure that the website is secure, HTML encryption software will be used to encrypt the contents of the website, allowing only those with the correct username and password to access it. We will use encryption software such as TagsLock Pro v 2.22 to hide the source code of our HTML documents. To encrypt HTML using TagsLock PRO, you need to create a new project once, and re-use it later when the site content gets modified and needs re-uploading. In order to use this encryption software, a website using the UCONN Biomedical Engineering server will be created.

2.1.2.9 Power Supply

The power supply of this design is the same as that of Design 1. The device will mainly be run from an external power source by using a power cord. It will also be equipped with rechargeable backup batteries in case of a power failure. For the power supply, we plan on using a very generic universal power cord, which will plug into the back of our device and then also plug into the wall. For the backup power supply we

determined the best way would be to use nickel cadmium rechargeable batteries. The need for a backup battery is so the patient can take signs even if the power is gone.

2.1.3 Design 3

2.1.3.1 Objective

As we continued to update and revise our design, parts of the design changed. In our last two designs, we purchased a pulse oximeter probe to incorporate into our vital signs monitor. To save money, we created a design for a pulse oximeter probe that we will build. The respiratory belt used in the last design to measure respiratory rate has been replaced by a thermocouple, a more cost effective and accurate solution. Bluetooth wireless communication has been used in this design to transmit collected vital signs from the monitor to the client's computer. This removes the USB flashdrive and the need to physically transport vital signs data to the computer, as in previous designs. We also explored an effective way to enclose the inner circuitry of our device in this design. An AutoCad™ drawing of our casing will be sent to Toolless Plastic Solutions, who will take that file and manufacture a plastic casing. Buttons will be customized to increase accessibility and ordered through Grayhill Co. Finally, in this design we have included a method to transmit the vital signs data to the healthcare professional through a secure e-mail system rather than a website.

2.1.3.2 Thermometer

Like in Designs 1 and 2, to measure body temperature, a thermistor circuit will be used. The probe chosen for this is the Welch-Allyn # 02893-000 Sure Temp 690 Oral Probe from DREMed.com (as in Design 2). For our use as an oral temperature probe, the thermistor needs to be linearized (calibrated) around 98.6° F (37°C), for a temperature range of at least 90-104° F (32-40°C). After being linearized, the signal will be filtered, amplified, and then passed to the microprocessor where it will be analyzed and sent to an LCD screen to be displayed (as in Design 2). .

The thermometer will be tested by placing the probe in a beaker of water heated to a certain temperature and comparing the resulting temperature given by the thermometer to the actual temperature of the water. We feel an appropriate temperature range to test this would be from 32°C to 40°C. Final testing will be done by taking group members' temperature with the thermometer and comparing the reading with that taken by a commercial digital thermometer.

2.1.3.3 Pulse Oximeter

To measure blood oxygen saturation, a pulse oximeter will be used. The circuit design is the same as that from Designs 1 and 2, but unlike those previous designs, the finger probe will be constructed instead of bought. The block diagram of the pulse oximeter below shows an overview of the circuits that are involved and will be included in the vital signs monitoring device (Fig. 5).

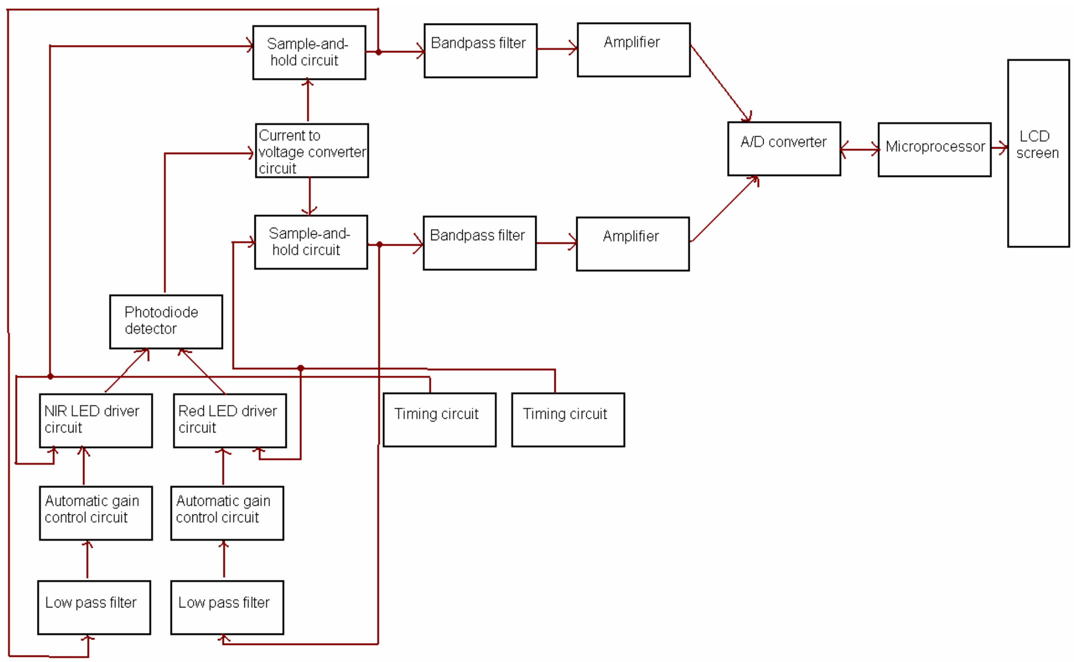


Figure 5. Pulse Oximeter Circuit Block Diagram

To build the finger probe that we will use with our device, we will need a red LED, a NIR LED, and a photodiode. The LEDs will be placed opposite the photodiode within a casing that can be clipped to a finger (Fig. 6).

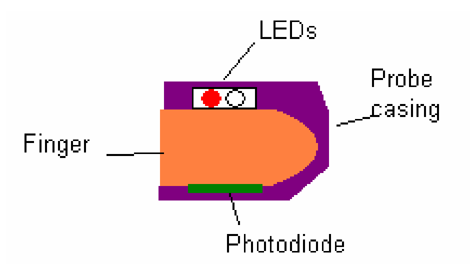


Figure 6. Finger Probe Diagram

One LED will work at a red wavelength (660nm) and the other at a near-infrared (NIR) wavelength (910nm). Also, in the probe will be a photodetector that will detect the light transmitted through the finger.

The complete schematic (Fig. 7) of the pulse oximeter shows how each of the different circuits previously described in Designs 1 and 2 will be integrated into a whole.

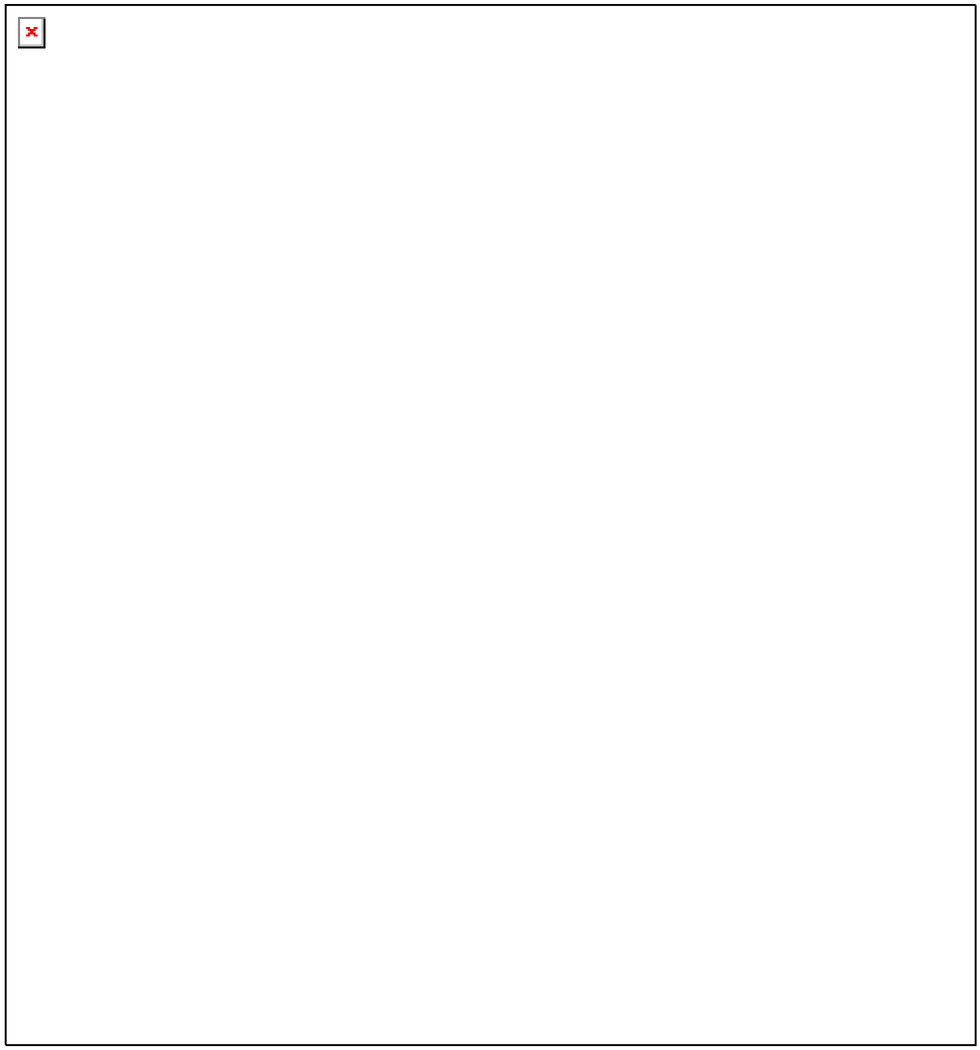


Figure 7. Pulse Oximeter Circuit Diagram

Calibration of the pulse oximeter will be done through the lookup table stored on the microprocessor. Manufacturers of pulse oximeters determine calibration curves or lookup tables for their devices. The pulse oximeter will be calibrated tested through a pulse oximeter simulator, a device designed to test the accuracy of pulse oximeters. We plan to find a simulator to use at a local hospital or the UConn Health Center.

Heart Rate

Pulse oximetry will also be used to determine heart rate. There are pulsatile signals detected in the intensity of the detected light by the photodiode. One pulse is one cardiac cycle. The microprocessor will count the pulses to determine heart rate (beats per minute), which will be displayed on an LCD screen. This function will be tested by comparing the heart rate given by the pulse oximeter to that of a group member taken manually.

2.1.3.4 Non Invasive Blood Pressure

As in Design 2, blood pressure will be automatically measured through the oscillometric method [15]. The blood pressure cuff used will be a DRE Adult single lumen cuff from DREMed.com at a cost of $37.00, before shipping and tax. The cuff will be inflated by a Sensidyne AA Series Micro Air Pump. A microprocessor, second to the microprocessor controlling the rest of the device, will control the inflation of the cuff. The sensor used to sense cuff pressure will be the NPC-1210 low-pressure sensor from GE. Once the pressure sensor determines that the cuff has been inflated to 160mmHg, the cuff will deflate slowly at a rate of 2-3mmHg/sec. Deflation will occur through a release valve (brand to be determined).

As blood begins flowing through the brachial artery again, it will cause small pulsations that will be picked up by the pressure sensor in the cuff. This waveform will be analyzed by the microprocessor to determine the systolic and diastolic pressures. This process is exactly the same as describe in Design 2. Due to the safety issues that arise with automatic blood pressure systems, we have incorporated a “kill switch” into our design (Fig 17) [18]. If at any time during the blood pressure measurement the user wants to stop the inflation of the cuff and rapidly deflate it, they just need to press the vital signs monitor “On/Off” button. This will cut power to the whole device and open the pressure release valve. This method bypasses the microprocessor, avoiding any software bugs that an emergency stop button might encounter.

As stated in Design 2, the automated blood pressure system will be calibrated experimentally. This will be done through establishing a threshold voltage by which correct pressure measurements for systolic and diastolic pressures can be made. Final testing of the device will be done by comparing its blood pressure readings to those of a sphygmometer.

2.1.3.5 Respiratory Rate

Unlike Designs 1 and 2, respiratory rate in this design will be measured using a thermocouple. The thermocouple will be clipped to the client’s nose and will measure the change in temperature caused by inspiration and expiration (Fig. 8). The thermocouple will convert the changes in temperature it detects to changes in voltage. Through experimentation, voltages thresholds will be set to define the changes in temperature that correspond to inspiration and expiration. By counting the number of inspiration and expiration pairs that occur in a given period of time, we can determine respiratory rate.

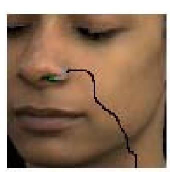


Figure 8. Image of Thermocouple Nose Clip

The voltage from the thermocouple will be linear over our range (approx. 65°F to 98°F), so the signal from the thermocouple only needs to be filtered and amplified before being A/D converted and processed by the microprocessor.

As mentioned previously, this circuit will be calibrated experimentally. Voltage output from the thermocouple will be measured for inspiration and expiration. From these measurements voltage thresholds will be set for inspiration and expiration. Testing will be done by comparing the readings from our respiratory rate monitor to those taken by the Biopac respiratory belt from the Biopac software used in the ENGR 166 lab.

2.1.3.6 Weight

Weight will be monitored by the same system discussed in Design 2, to ensure patient health. The scale that will be used is the Homedics SC-200 Digital Scale. We plan on taking apart the scale and breaking the connection between the circuit and its digital display. From here we will connect the scale's circuit to one of our output displays. The scale will already have been calibrated and tested by its manufacturer. We will do additional testing by comparing known weight values (dumbbells) to the values displayed by the scale when we place the weights on it.

2.1.3.7 Secure E-mail System

In the first two designs, we sent the vital signs data through a secure website. Another viable option that we explore in this design is a secure e-mail system. This can be accomplished through certifiedmail.com. This website provides the software necessary to protect e-mail using transparent encryption. It provides easy to use software that the recipient of the e-mail does not need to download in order for complete security to occur. For starters there is no password required and information is automatically secured every time with the Certified Mail software. It is also possible to track the e-mail to determine that the e-mail was received and who opened it. A time download and $10 per month provides these features.

2.1.3.8 Power Supply

The power supply of this design is the same as that of Designs 1 and 2. The device will mainly be run from an external power source by using a power cord. It will also be equipped with rechargeable nickel cadmium backup batteries in case of a power failure.

2.1.3.9 Bluetooth

Instead of using a USB device to move store patient data, in this design we will transmit the data collected by the vital signs monitor to the client's computer wirelessly using Bluetooth. We will purchase the EmbeddedBlue eb100-SER OEM Bluetooth Serial Module from A7 Engineering for $40 to integrate into our vital signs monitor to provide Bluetooth connectivity. This module contains all the components of the Bluetooth stack on the board so that no additional host processor code is needed. The interface between our host processor and the eb100-SER radio will be done through

UART communication. Assuming that our clients' computers are not Bluetooth ready, a USB Bluetooth dongle will be purchased (usually at $10-$20) to provide connectivity on the PC end. Our Bluetooth communications system will be calibrated through UART communication with any extra equipment necessary provided by the BME 252 lab. It will be programmed to set up a network with the Bluetooth USB dongle when it detects it. The Bluetooth system will be tested by acquiring vitals signs from the monitor and sending them to a computer in the design lab to which the USB dongle is installed. The vital signs monitor will be placed at different ranges within 10 meters to determine signal strength at different ranges and the optimum range for data transmission.

2.1.3.10 Pushbuttons

An important feature of our design is the buttons involved. We will include buttons with a Universal Symbol or Braille, so individuals with vision impairment can use them. A company that offers customizable buttons is Grayhill. The model button from Grayhill that fits our project is a rectangular button that is about 15 by 20 millimeters. These buttons are very easy to secure. The buttons require a proper size whole to be drilled in the area where the buttons will be placed. The buttons will then be snapped into the hole. Once the button is snapped into the hole, it has wings which will open to secure it. The only visible problem with this product is that the button may be too small and also that we are not yet aware of the price. We are awaiting a price quote from the Gray Hill Company.

The buttons will act like a switch, either turning the power on or off. The start button will be connected to the beginning of the circuit. There will be a switch in the circuit that will either be open if the device is "off" or closed if power is to be given to the entire circuit. When the start button is pressed, the switch on the circuit will close allowing for the power supply to be sent to and power the rest of the circuit.

2.1.3.11 Casing

In order to safely enclose the internal circuitry of our design, a plastic enclosure needs to be manufactured. We will use the company Toolless Plastic Solutions to manufacture our casing. In order for this company to manufacture our case, we need to submit an AutoCad™ drawing of the final casing design. Since we will not know the exact size and placement of all 6 holes for the LCD screens, and the various I/O ports in the casing, the design will be submitted in the spring semester when all the parts have been ordered and more about the final design is known. Toolless Plastic Solutions requires no tooling or molds, and therefore will be a cost-effective way to obtain an enclosure for our design [7]. The company uses CNC (Computer Numerical Control) machining and fabrication process to build plastic casings. We will not know the exact price of the casing until a design is sent for a quote.

2.1.3.12 Processing, Display, and Alarm

As in Design 2, the processor we are going to use for this design is the Blackfin ADSP-BF535P Digital Signal Processor by Analog Devices. Like the PIC

microcontrollers, the Blackfin contains an internal analog to digital converter. We will use the PF pins (I/O ports on microcontrollers) on the Blackfin to function as inputs for the transducers and outputs for the LCD screens and speaker. Due to the Blackfin's abilities, it should be the only microprocessor we need for our device. The Blackfin can take C/C++ code as well as LabVIEW Vi's.

After the data has been processed the information will be sent to 4 different areas: the LCD displays, the speech module, the speaker, and alarm. For the LCD displays, 4 displays from Crystal Fontz will be used. These displays are the same ones used in Design 2. Each measures 122mm x 44mm, with a viewing area of 99mm x 24mm, and a character height of 8.06mm.

The same process and parts to produce audio process in Designs 1 and 2 will also be used in this design. The Magnevation SpeakJet IC will be used in conjunction with the TTS256 Text to Code IC to produce speech. To play these sounds (and the alarm), a commercial .5W, 8 Ohm speaker will be purchased. The alarm will include audio and visual features that will turn on when the patient's vital signs become abnormal.

2.2 Optimal Design

2.2.1 Objective

Due to the increasing number of chronic illnesses, along with the shortage of nurses, home monitoring is becoming more and more of a necessity. Patients that require frequent healthcare monitoring can now have this done in the comfort of their own home. An important tool for home health monitoring is the vital signs monitor. Our accessible home vital signs monitoring system will have the capability to non-invasively gather a patient's heart rate, blood pressure, blood oxygen level, body temperature, weight, and respiratory rate, and then send this data to their corresponding healthcare provider. To send this data, we will create a password protected encrypted website to which patients can upload their vital signs. This accessible home vital signs monitoring system design is an accurate and consistent way to obtain a patient's vital signs, regardless of the caregiver's skill level. To accommodate all users, including our clients, the monitoring system was designed as simple and user friendly as possible.

To maximize the simplicity of our design and make it accessible to all of our clients, the buttons on the front panel of the monitor will be large and printed with either Braille or a universal symbol, allowing patients who are vision-impaired or have arthritis to successfully operate the monitor. Also to accommodate vision-impaired clients, a text-to-speech function will be implemented to allow the monitor to audibly tell the patients what their current vital signs are. In addition, six bright LCD screens with wide viewing angles will be used to display the patients' vital signs. A visual and audio alarm will be installed to alert clients if their vital signs are abnormal. An illustration of our design followed by a flowchart of our system operation can be seen in Figs. 9 and 10.

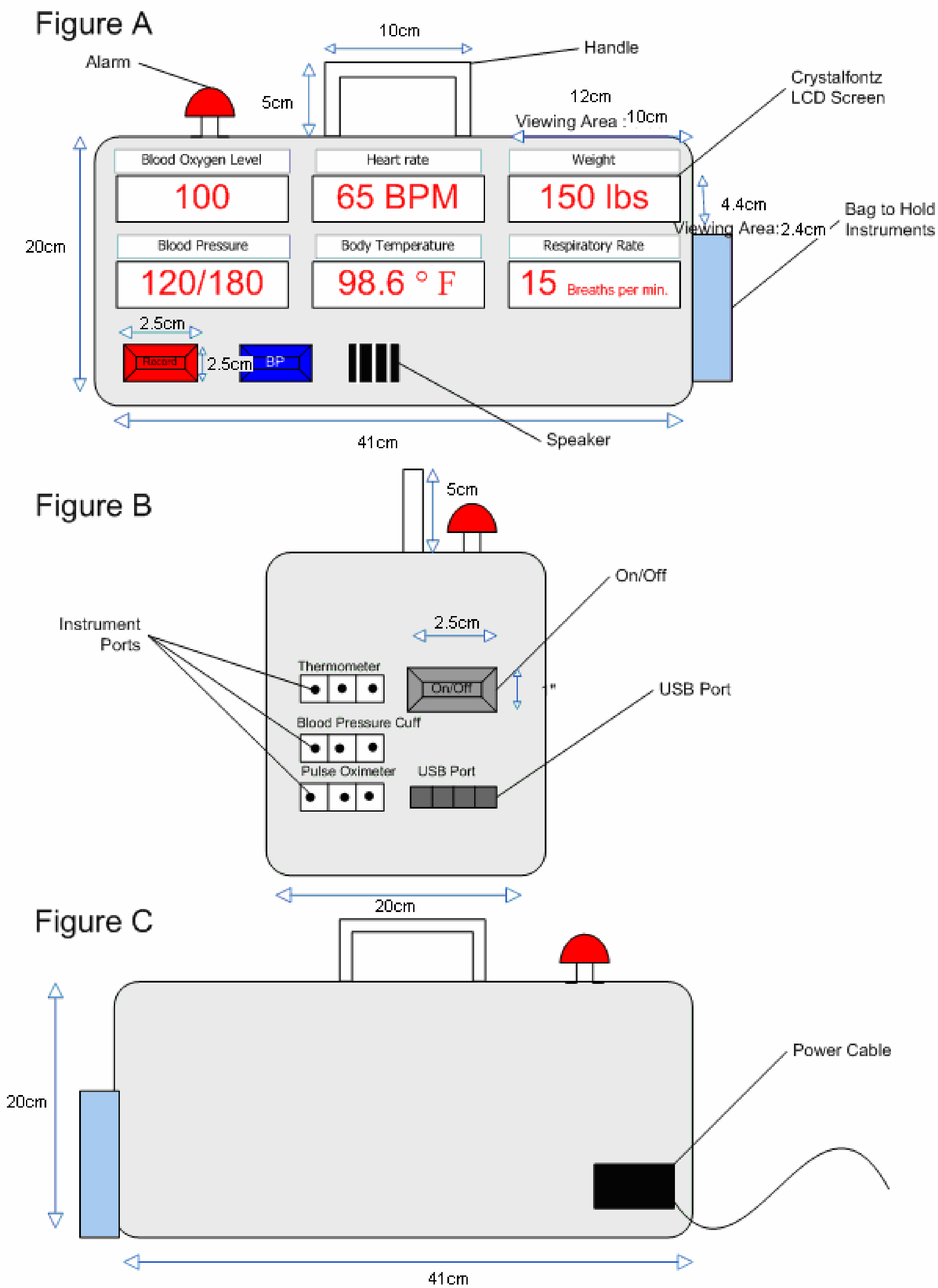


Figure 9. Illustration of Design

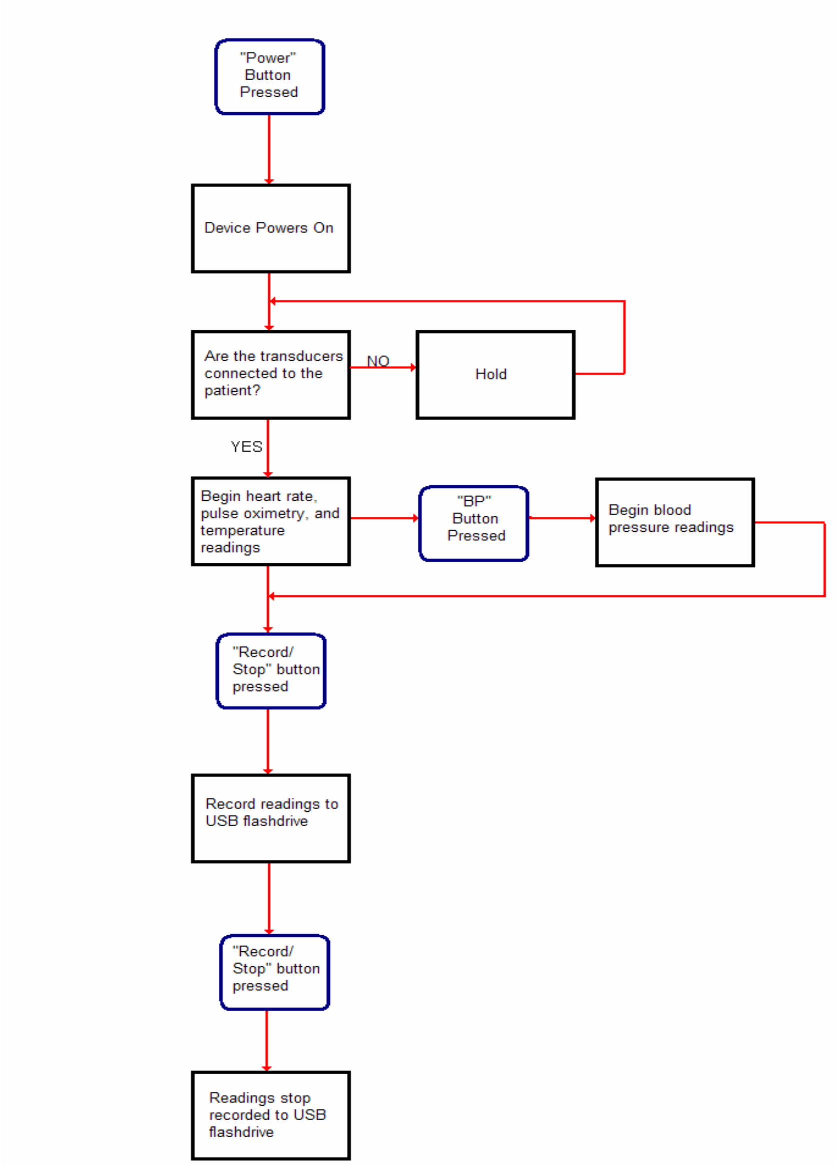


Figure 10. Flowchart of Accessible Vital Signs Monitor Operation

2.2.2 Subunits

2.2.2.1 Thermometer

To measure body temperature, a thermistor circuit will be used. The thermistor will be in the form of a commercially purchased, oral temperature probe. The probe we have chosen for this is the Welch-Allyn # 02893-000 Sure Temp 690 Oral Probe from DREMed.com for a cost of $74.00, before shipping and tax (Fig. 11):

http://www.dremed.com/catalog/product_info.php/products_id/1214

Figure 11. Welch-Allyn Sure Temp 690 Oral Temperature Probe

The thermistor within the probe will convert changes in temperature to changes in voltage. Unfortunately, thermistors are inherently non-linear. The Steinhart-Hart equation describes the resistance-temperature curve of a thermistor [17]:

$$\frac{1}{T} = a + b\ln(R) + c\ln^3(R)$$

where T is the temperature in kelvins, R is the resistance in ohms, and a, b, and c are constants called the Steinhart-Hart parameters which will be provided by the thermistor manufacturer. This output can be linearized through the use of a Wheatstone bridge (Fig. 12).

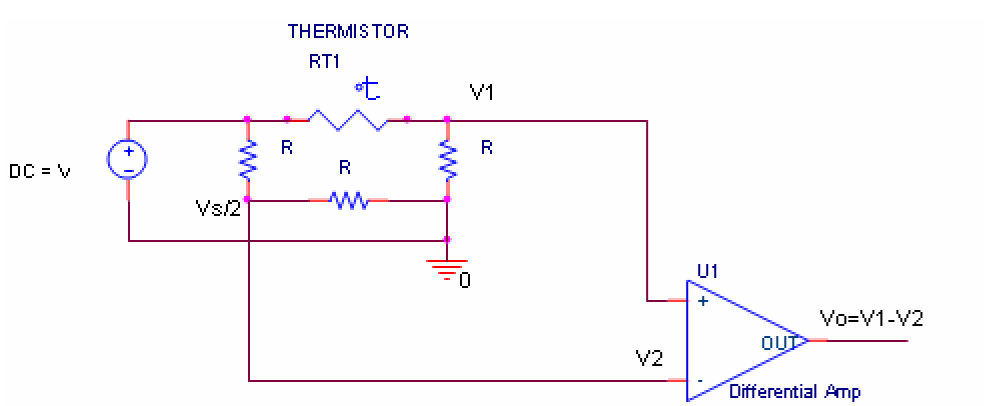


Figure 12. Thermistor Linearizing Circuit [11]

Thus, the resistance of the thermistor, RT1, can be modeled by the first order equation [10]:

$$R(T_1) \cong R[1 + \alpha\Delta T],$$

where R is the resistance of the other resistance in the Wheatstone bridge, α is the temperature coefficient, and ΔT is the change in temperature from the reference temperature ($\Delta T = T - T_o$) in degrees Kelvin. The reference temperature (T_o) of the

thermistor is given by the manufacturer and for medical thermistors it is usually around 300°K. The temperature coefficient, α, can be calculated from the following equation:

$$\alpha = \frac{\frac{d(\mathrm{R}(\mathrm{T}_1))}{d\mathrm{T}}}{\mathrm{R}(\mathrm{T}_1)} = -\frac{\beta}{\mathrm{T}^2},$$

where β is a temperature constant, typically around 4000°K [10]. The value of the resistors, R, used to linearize the thermistor will be determined from the reference temperature and other values given by the manufacturer (β or α) using the above equations. For our use as an oral temperature probe, the thermistor needs to be linearized (calibrated) around 98.6° F (37°C), for a temperature range of at least 90-104° F (32-40°C). When linearizing the thermistor, we must be careful to keep the accuracy of the thermometer high ($\pm$ .1°C) so as to be able to take appropriate measurements.

After being linearized, the signal will be sent to a low-pass filter to remove any noise. The cutoff frequency for the filter should be less than 40Hz to remove any noise from room lights and other sources ($f_c = \frac{1}{2\pi R_2 C}$) [9]. Possible values for R2 and C are 1820Ω and 2.2μF. The signal will be sent to a non-inverting amplifier to be amplified and then passed to the microprocessor where it will be analyzed and sent to an LCD screen to be displayed (Fig. 5).

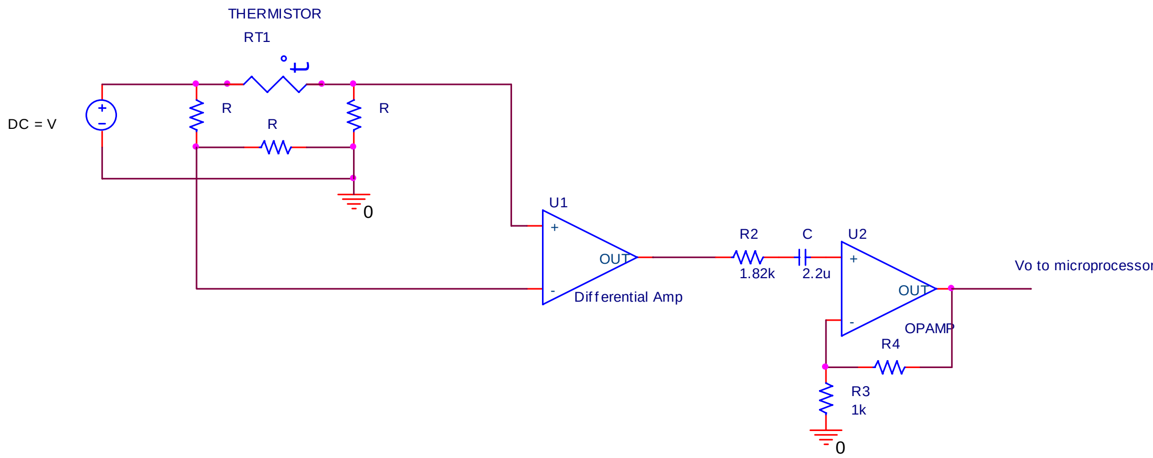


Figure 13. Thermometer Circuit

Values for R3 and R4 will be determined from gain equation for non-inverting amplifiers:

$$\frac{V_{out}}{V_{in}} = 1 + \frac{\mathrm{R}_4}{\mathrm{R}_3}.$$

The target gain for the amplifier will be based on the input current or voltage for the microprocessor.

The thermometer will be tested by placing the probe in a beaker of water heated to a certain temperature and comparing the resulting temperature given by the thermometer to the actual temperature of the water. This will be done over a range of temperatures to determine the thermometer's actual operating range and to assure that is within the appropriate range to measure body temperature. We feel an appropriate temperature range to test this would be from 29°C to 43°C. It will be made sure not to test with a temperature so hot that it burns the thermometer. Final testing will be done by taking group members' temperature with the thermometer and comparing the reading with that taken by a commercial digital thermometer.

2.2.2.2 Pulse Oximeter

To measure blood oxygen saturation, a pulse oximeter will be used. Pulse oximetry uses the optical properties of blood to determine oxygen saturation. Blood oxygen saturation (SpO_2) is defined as the ratio of oxyhemoglobin (HbO_2) to the total concentration of hemoglobin in the blood ($Hb + HbO_2$):

$$\mathrm{SpO_2} = \frac{[\mathrm{HbO_2}]}{[\mathrm{Hb} + \mathrm{HbO_2}]}.$$

This can be determined by measuring the difference in the light absorption spectra of oxyhemoglobin and deoxyhemoglobin [16]. Assuming that the transmission of light through the arterial bed in the finger is only influenced by the concentrations of Hb and HbO_2 and their absorption coefficients at two measurement wavelengths (red and near infrared), then the light intensity will follow the Beer-Lambert Law. Thus, for an artery of length *l*, through which light of intensity I_{in} passes:

$$I_1 = I_{in1} 10^{-(\alpha_{o1} C_o + \alpha_{r1} C_r) l} \text{ at wavelength } \lambda_1\text{, and}$$
$$I_2 = I_{in2} 10^{-(\alpha_{o2} C_o + \alpha_{r2} C_r) l} \text{ at wavelength } \lambda_2,$$

where I_1 and I_2 are the intensities of the light passing through the artery at each wavelength, C_o is the concentration of HbO_2, C_r is the concentration of Hb, α_{on} is the absorption coefficient of HbO2 at wavelength λ_n,, and α_{rn} is the absorption coefficient of Hb at wavelength λ_n.. Therefore, if

$$R = \frac{\log\left(I_1 / I_{in1} \right)}{\log\left(I_2 / I_{in2} \right)},$$

then blood oxygen saturation can be calculated from

$$\mathrm{SpO_2} = \frac{C_o}{C_o + C_r} = \frac{\alpha_{r2} R - \alpha_{r1}}{(\alpha_{r2} - \alpha_{o2}) R - (\alpha_{r1} - \alpha_{01})}.$$

Circuit Design

The block diagram of the pulse oximeter below shows an overview of the circuits that are involved and will be included in the vital signs monitoring device (Fig. 14).

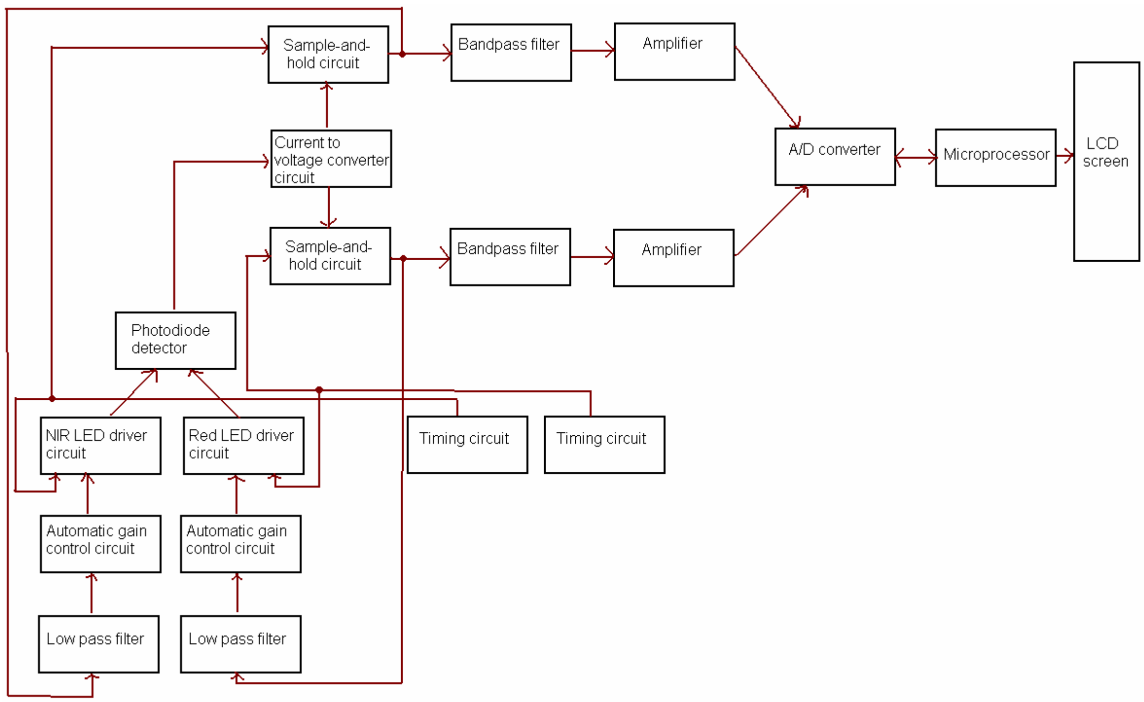


Figure 14. Pulse Oximeter Circuit Block Diagram

To build the finger probe that we will use with our device, we will need a red LED, a NIR LED, and a photodiode. The LEDs will be placed opposite the photodiode within a casing that can be clipped to a finger (Fig. 15).

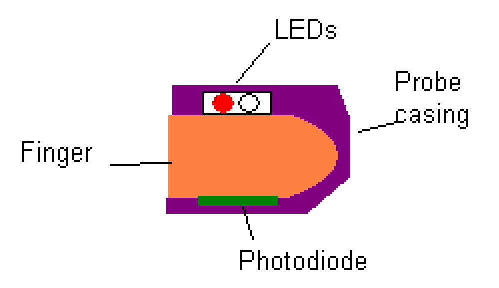


Figure 15. Finger Probe Diagram

One LED will work at a red wavelength (660nm) and the other at a near-infrared (NIR) wavelength (910nm). Also, in the probe is a photodetector that will detect the light transmitted through the finger. The red LED used in the probe will have been manufactured to give high intensity output, and the NIR LED will have been designed to

be pulsed, so that its peak power can be increased without increasing its average power. By pulsing both light sources, only one photodiode is needed to detect the light transmitted through the finger [16].

To transmit light, the LEDs need to be driven by a constant current source. This can be done by a non-inverting op amp combined with a FET (Fig. 16). In this circuit, the current driving the LED is given by $I_{LED}=(V_{in}-1.5V)/R$, because LEDs usually need 1.5V to turn on.

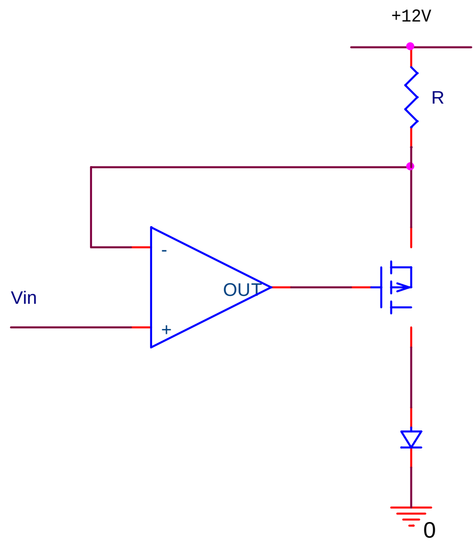


Figure 16. Circuit for Constant Current LED Driver

To control the pulsing of the LEDs, a timing circuit needs to be used. For this, we will use a 555 timer circuit (Fig. 17). The 555 timer will supply 50μs pulses to the LEDs at a rate of 1 kHz. This is well above the maximum frequency in the arterial pulse, which is never more than a few Hz.

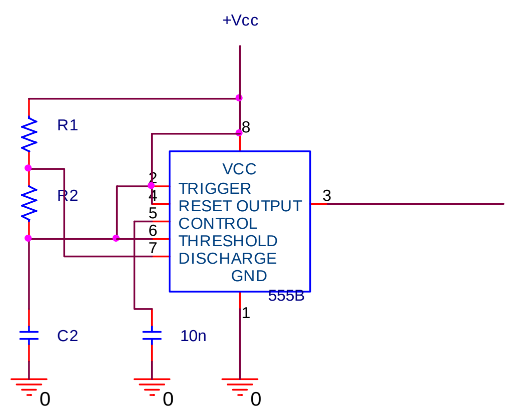


Figure 17. Timing Circuit

The values of the resistors can be determined from

$$T_1 = .7(R_1 + R_2)C_2 \text{ and } T_2 = .7R_2C_2$$

where T_1 is the pulse length (50μs) and T_2 is the rate (1kHz or 1ms). Thus, values for R1, R2, and C2 are 56kΩ, 3.3kΩ, and 22nF respectively. The 10nF capacitor connected to the control will be used to eliminate any electrical noise from the timer.

Finally, an n-channel enhancement-mode MOSFET connected across the each LED is used to pulse the output from them (Fig. 18).

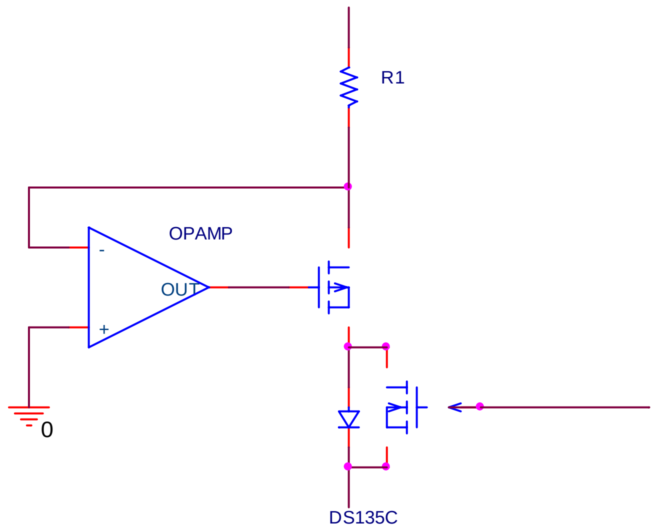


Figure 18. Circuit to Pulse the LEDs

In the receiving end of the circuit is the photodetector. The photodetector used in pulse oximetry probes is a photodiode. The photodiode detects the light transmitted through the finger as current [16]. To amplify the signal, the photocurrent must be converted into a voltage with moderate output impedance. This can be done by using an op-amp configured for current-to-voltage conversion (Fig. 19). The photodiode provides a high junction resistance, so the op amp should be a FET type with high input impedance [16]. The negative input of the op amp acts as a virtual ground, making the output of the op amp $v_o = IR$. Thus, it is common practice to make the value of R as high as tens of MΩ with the value of C as 47pF [16].

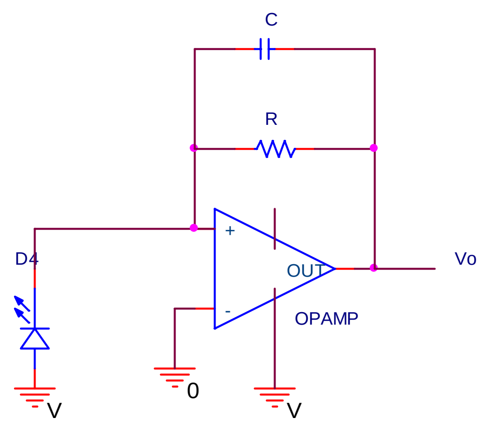


Figure 19. Current to Voltage Photodiode Conversion Circuit

Because the LED light is pulsed, sample-and-hold circuits are needed to reconstitute the waveforms at each of the two wavelengths. The timing circuits that were used to control the red and NIR LED drivers also are used to provide the control pulses for their corresponding sample-and-hold circuits [16]. A simple sample-and-hold circuit can be created from a FET switch, capacitor, and op amp (Fig. 20).

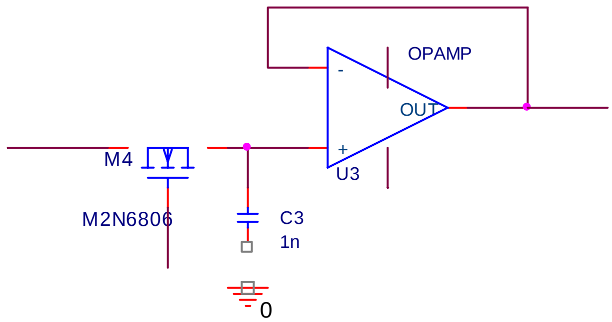


Figure 20. Sample-and-hold Circuit

Once the signal goes through the sample-and-hold circuit, it is sent through a band pass filter with cutoff frequencies .5Hz and 5Hz to eliminate high frequency noise and the d.c. offset. Then, it is amplified (resistor values to be determined) and sent through an A/D converter and the microprocessor to be analyzed. A lookup table stored in the microprocessor will be used to calculate SpO_2 values. This signal is also sent through a low pass filter (f_c = .1Hz) to extract the d.c. value of the transmitted signal, which is then sent to an automatic gain control circuit. The gain control circuit adjusts the light intensity from the LEDs so that the d.c. level always remains at the same value, whatever the thickness of the patient's skin, tissue, etc. This circuit is implemented by feeding the d.c. signal to one input of a differential amplifier. The other input to the amplifier is a constant reference voltage. The output of the differential amplifier, the voltage difference between the two inputs, is used to generate the voltage that sets the value of the LED currents [16]. The complete schematic (Fig. 21) of the pulse oximeter shows how each of the different circuits previously described will be integrated into a whole.

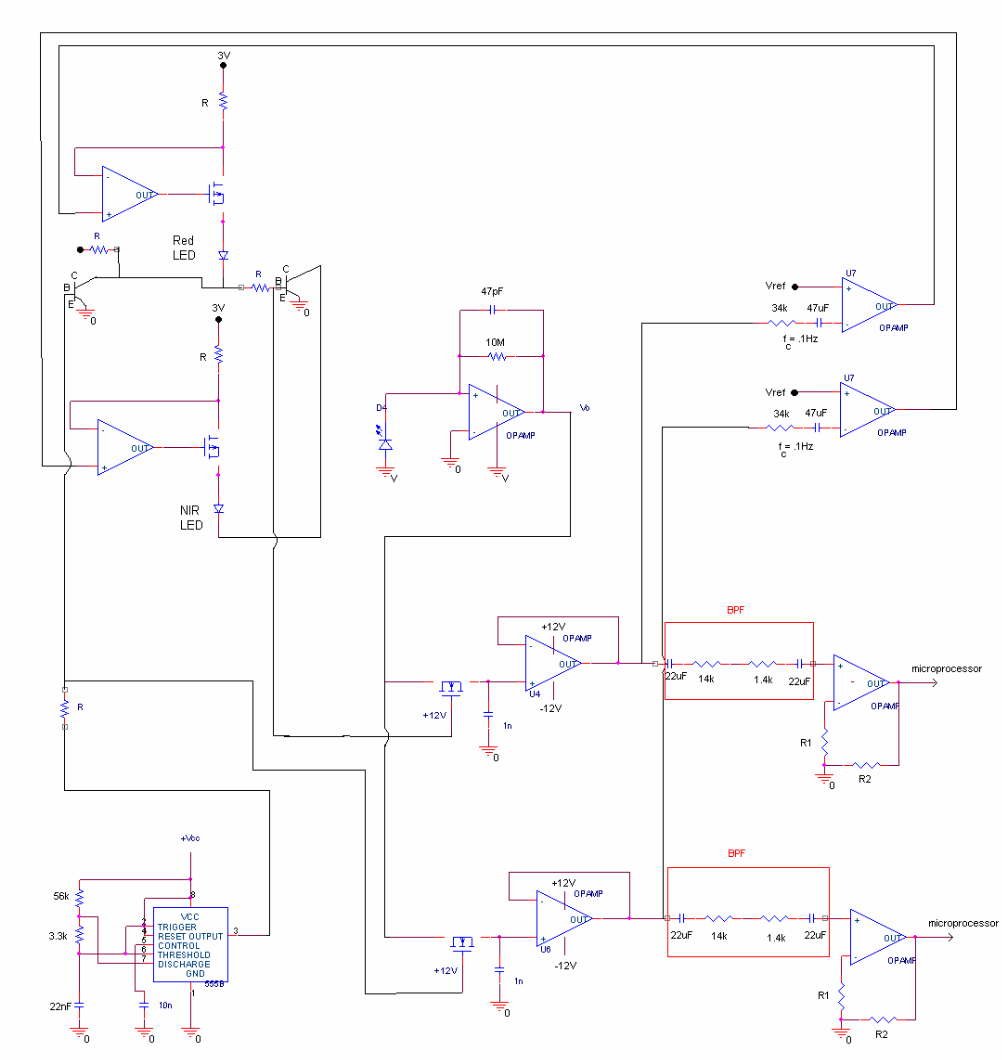


Figure 21. Pulse Oximeter Circuit Diagram

Calibration of the pulse oximeter will be done through the lookup table stored on the microprocessor. Due to the scattering effects of blood, Beer's Law does not apply for a pulse oximetry system [19]. Therefore, the blood oxygen saturation equations explained previously are good for theory but not for practice. As such, pulse oximeters are usually calibrated by comparing the oximeter *R* value (SpO_2 ratio) to the oxygen saturation ratio obtained from *in vivo* samples using human test subjects. Manufacturers of pulse oximeters do this and determine calibration curves or lookup tables for their devices. The pulse oximeter will be calibrated tested through a pulse oximeter simulator, a device designed to test the accuracy of pulse oximeters. We plan to find a simulator to use at a local hospital or the UConn Health Center.

Heart Rate

Pulse oximetry will also be used to determine heart rate. There are pulsatile signals detected in the intensity of the detected light by the photodiode (Fig. 22).

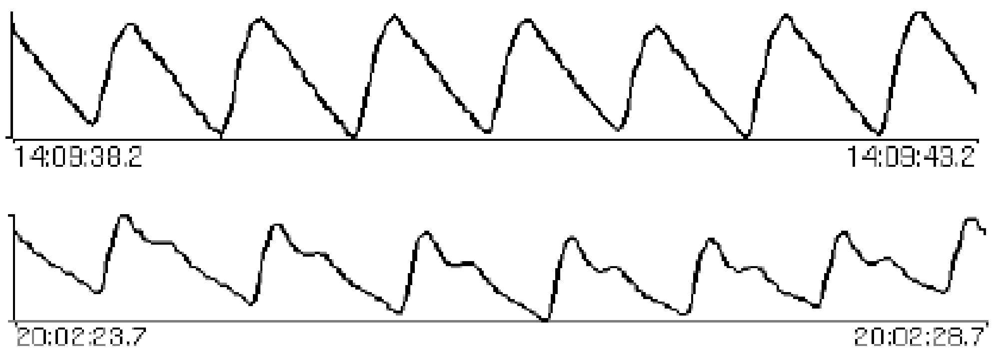


Figure 22. Pulsatile Signals Found in the Intensity of Detected Light [16].

One pulse is one cardiac cycle. The microprocessor will count the pulses to determine heart rate (beats per minute), which will be displayed on an LCD screen.

The microprocessor will be programmed (calibrated) to count the peaks of the signal for 10 seconds. Multiplying this by 6 will give the heart rate in beats per minute. This function will be tested by comparing the heart rate given by the pulse oximeter to that of a group member taken manually.

2.2.2.3 Non Invasive Blood Pressure

Blood pressure will be automatically measured through the oscillometric method [15]. This is done by wrapping a blood pressure cuff around the upper arm and inflating it until the pressure around the arm due to the cuff collapses (or occludes) the brachial artery. The cuff is then slowly deflated. As the cuff deflates, blood starts pumping through the brachial artery causing minute vibrations of .5 to 1 mmHg in the cuff [4]. The pressure at which these vibrations start is the systolic pressure, and the pressure at which they stop is the diastolic pressure [5]. The block diagram in Fig. 26 illustrates how this method will be used to measure blood pressure in the accessible vital signs monitoring system. Each system in the flow chart is described in more detail in the following paragraphs.

When the blood pressure "Start" button on the vital signs monitor is pressed, the blood pressure cuff will be inflated to about 40mmHg above normal (160mmHg). The blood pressure cuff used will be a DRE Adult single lumen cuff from DREMed.com at a cost of $37.00, before shipping and tax (Fig. 23).

http://www.dremed.com/catalog/ product_info.php/cPath/56_121_241_242/products_id/194

Figure 23. DRE Adult Single Lumen Blood Pressure Cuff

The cuff will be inflated by a Sensidyne AA Series Micro Air Pump. A microprocessor, second to the microprocessor controlling the rest of the device, will control the inflation of the cuff. The sensor used to sense cuff pressure will be the NPC-1210 low-pressure sensor from GE. Once the pressure sensor determines that the cuff has been inflated to 160mmHg, the cuff will deflate slowly at a rate of 2-3mmHg/sec. Deflation will occur through a release valve (brand to be determined). A basic circuit for the automated blood pressure system is seen in Figure 24. The pump and valve are powered by the battery and controlled by the microprocessor. The pressure sensor also receives power from the battery, and it sends signals to the microprocessor. Amplifier resistor values (R1 and R2) will be determined experimentally.

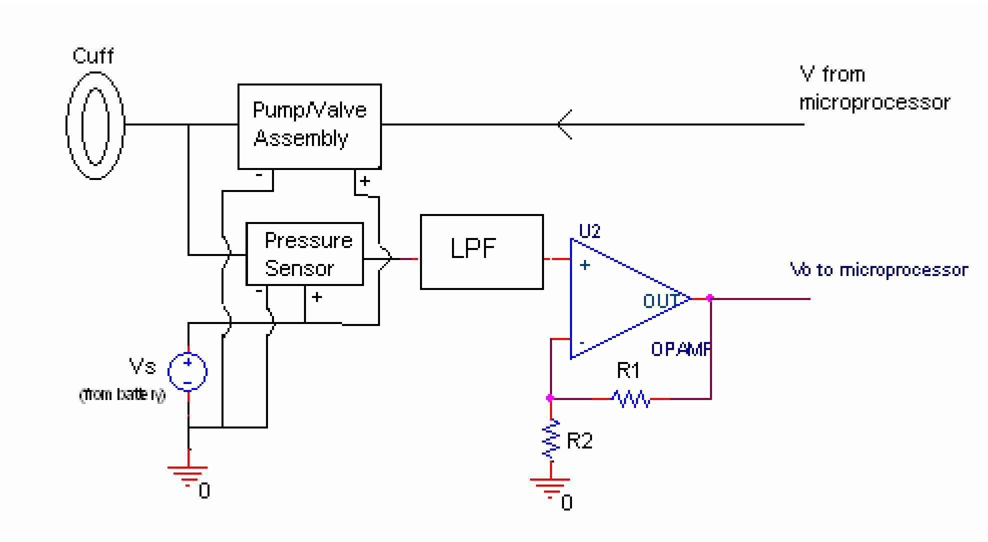


Figure 24. Automated Blood Pressure System Circuit

As blood begins flowing through the brachial artery again, it will cause small pulsations that will be picked up by the pressure sensor in the cuff (Fig. 25). This waveform will be analyzed by the microprocessor to determine the systolic and diastolic pressures.

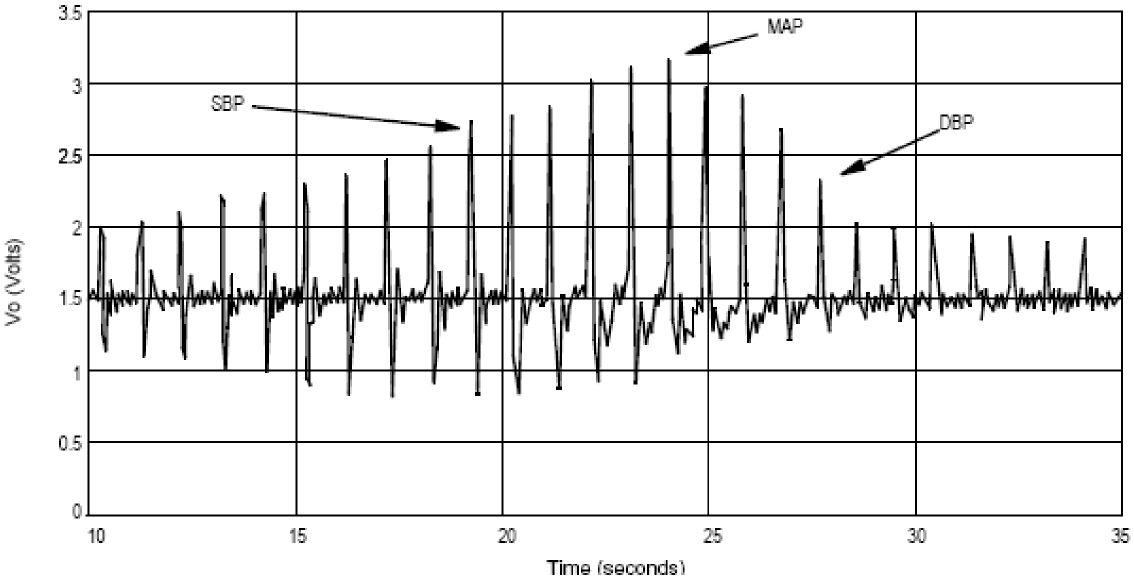


Figure 25. Blood Pressure Waveform Picked Up by Pressure Sensor [17]
Where: MAP = Maximum Arterial Pressure
SBP = Systolic Blood Pressure
DBP = Diastolic Blood Pressure

A threshold voltage level will be set. This will be done by experimentally comparing blood pressure readings from a sphygmometer or other commercial device to those detected by our pressure sensor. Once 4 pulsations peak above the threshold level, the voltage will be recorded and from that value the systolic pressure determined. The microprocessor will continue to monitor the blood pressure readings and diastolic pressure will be taken when the voltage drops below the threshold voltage for 2 pulsations. After the diastolic pressure is determined, a command from the microprocessor will deflate the cuff quickly and completely.

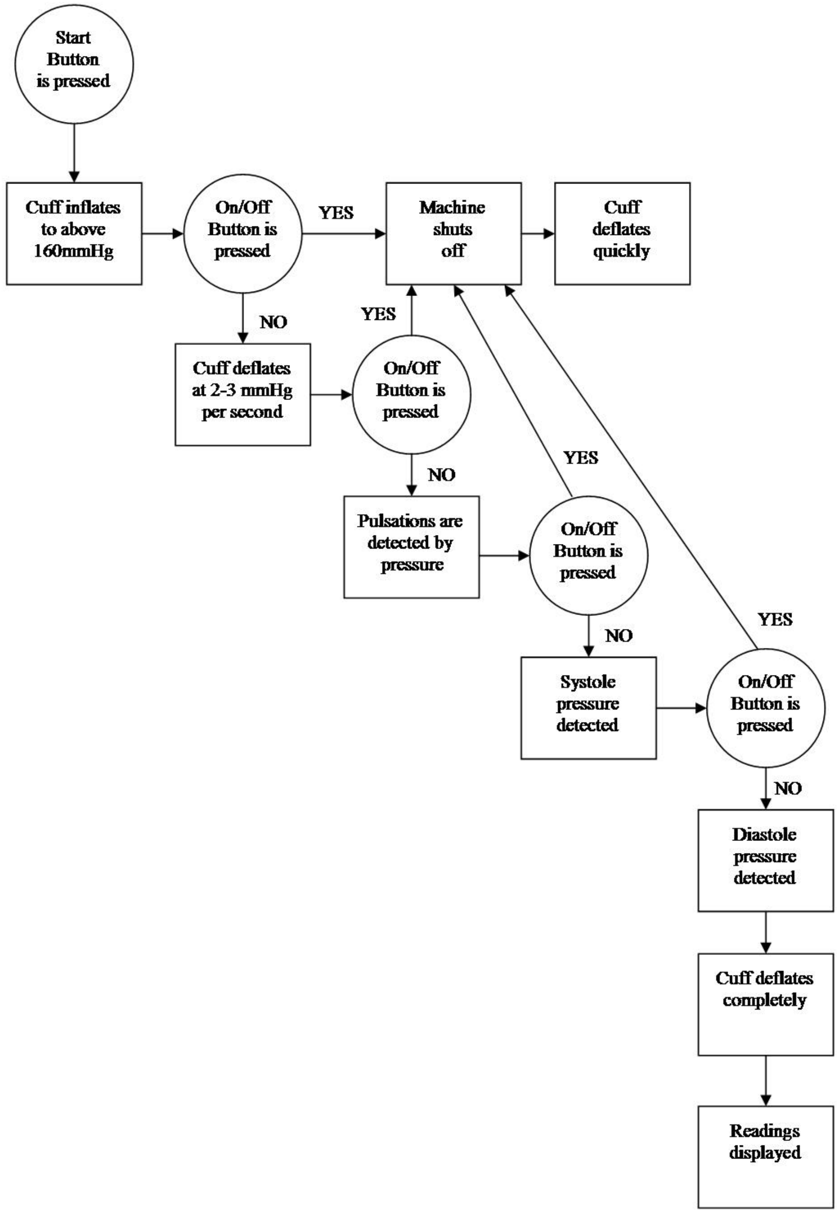


Figure 26. Block Diagram of Automatic Blood Pressure Measuring System

Due to the safety issues that arise with automatic blood pressure systems, we have incorporated a "kill switch" into our design (Fig 26) [18]. If at any time during the blood pressure measurement the user wants to stop the inflation of the cuff and rapidly deflate it, they just need to press the vital signs monitor "On/Off" button. This will cut power to the whole device and open the pressure release valve. This method bypasses the microprocessor, avoiding any software bugs that an emergency stop button might encounter.

As stated previously, the automated blood pressure system will be calibrated experimentally. This will be done through establishing a threshold voltage by which correct pressure measurements for systolic and diastolic pressures can be made. Final

testing of the device will be done by comparing its blood pressure readings to those of a sphygmometer. In the testing, the sphygmometer will be operated by a nurse or other individual who is familiar with manually measuring blood pressures and does so often. Nevertheless, we expect to see some slight differences in the measurements from our device and the sphygmometer because of the inherent degree of imprecision in manual blood pressure measurement. This is why it is important to have a professional operating the sphygmometer. Their experience with the device and the art of blood pressure measurement should reduce the likelihood of human error. Finally, the rapid cuff deflation will be tested by experimentation (turning the vital signs monitor off during use).

2.2.2.4 Respiratory Rate

Respiratory rate will be measured using a thermocouple. The thermocouple will be clipped to the client's nose and will measure the change in temperature caused by inspiration and expiration (Fig. 27). The thermocouple will convert the changes in temperature it detects to changes in voltage. Through experimentation, voltages thresholds will be set to define the changes in temperature that correspond to inspiration and expiration. By counting the number of inspiration and expiration pairs that occur in a given period of time, we can determine respiratory rate.

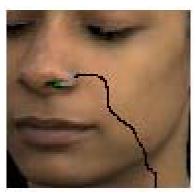


Figure 27. Image of Thermocouple Nose Clip

The circuit for the thermocouple will be powered by the battery. The voltage from the thermocouple will be linear over our range (approx. 65°F to 98°F), so the signal from the thermocouple only needs to be filtered and amplified (resister and capacitor values to be determined) before being A/D converted and processed by the microprocessor. Like the thermistor circuit, the thermocouple circuit will also include a Wheatstone bridge (Fig. 28). Values for the resistors, R, will be decided experimentally.

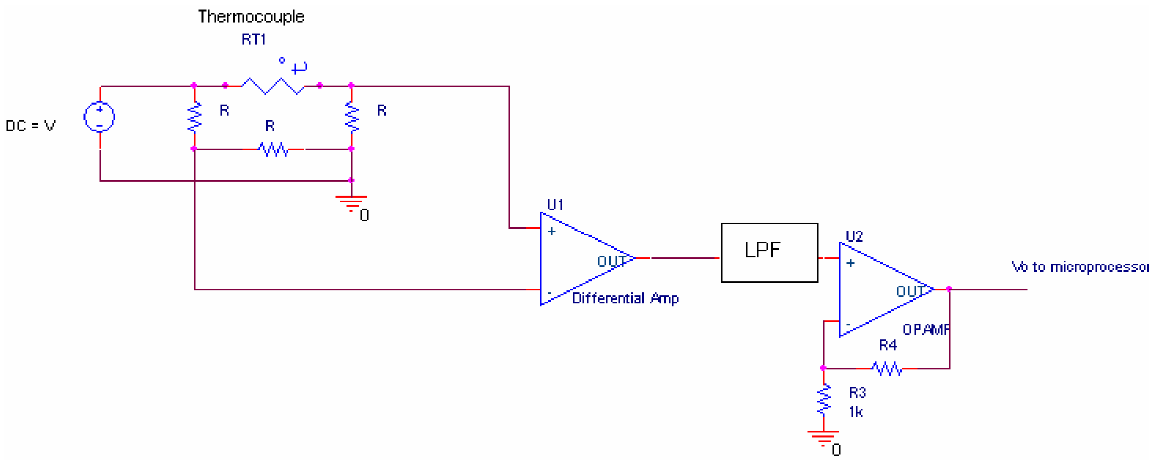


Figure 28. Circuit for Respiratory Rate

As mentioned previously, this circuit will be calibrated experimentally. Voltage output from the thermocouple will be measured for inspiration and expiration (most likely from being tested on group members). From these measurements voltage thresholds will be set for inspiration and expiration. Experiments will also be done to determine the optimum time period for measurement. Testing will be done by comparing the readings from our respiratory rate monitor to those taken by the Biopac respiratory belt from the Biopac software used in the ENGR 166 lab.

2.2.2.5 Weight

Weight is an important vital sign to monitor. In addition to ensuring proper eating habits, weight is used to determine medication doses. We will include weight monitoring into our vital signs monitor by buying a digital scale that exists on the market and connecting it to our device. The scale that will be used is the Homedics SC-200 Digital Scale (Fig. 29).

Figure 29. Homedics SC-200 Digital Scale

This scale was chosen because it fits quite well with our project. We figured with our clients we will have to build handles onto the scale so people will be able to hold on and not fall. The reason for this is that some of our clients are elderly and might not be able

to stand steady on their own. Also since this scale already has a main waist high base, it should not be difficult to connect handles or rails. The scale was also chosen because it is very inexpensive at $24.95 and it can be found at wholesalepoint.com. The scale has an on/off switch and requires only one 9V batters for power. As of now our main approach to connecting the scale to our device is a very simple and straight forward approach. We plan on taking apart the scale and breaking the connection between the circuit and its digital display. From here we just plan on simply connecting the scales circuit to one of our output displays instead.

The scale will already have been calibrated and tested by its manufacturer. We will do additional testing by comparing known weight values (dumbbells) to the values displayed by the scale when we place the weights on it

2.2.2.6 Microprocessor

The processor we are going to use for our design is the Blackfin ADSP-BF535P Digital Signal Processor by Analog Devices (Fig. 30). This processor is extremely versatile due to the fact that it can function as both a microcontroller and a DSP (Digital Signal Processor), allowing for either 100% DSP, 100% microcontroller, or a combination of the two [8]. This makes the Blackfin ideal for our design due to the fact that we are going to input and output the data like a microcontroller, but use the digital signal processing features to analyze and filter the signals (FIR and IIR filters). The Blackfin will function like the traditional microcontroller, taking the electric signals from the transducer, passing them through an analog to digital converter, and processing the information. Like the PIC microcontrollers, the Blackfin contains an internal analog to digital converter. There are many advantages for us in using digital signal processing rather than traditional 100 % microcontroller functions. Microcontrollers can be cheap and easy to assemble, but are difficult to calibrate and modify. Using DSP, one can more easily design and modify their work due to the fact that it is all computer based. Thus, one can rely on their software based filters much more. DSPs are also much faster than microcontrollers. A typical PIC microcontroller has a clock speed of about 20 MHz, whereas the Blackfin has a clock speed of 350 MHz (Table 2). We will use the PF pins (I/O ports on microcontrollers) on the Blackfin to function as inputs for the transducers and outputs for the LCD screens and speaker. Due to the Blackfin's abilities, it should be the only microprocessor we need for our device.

We also chose to use the Blackfin due it its versatility in programming code. The Blackfin can take C/C++ code as well as LabVIEW VI's. Since we have had more experience using LabVIEW, we felt that LabVIEW would be a more suitable code to program the processor. When designing a product with Blackfin, many helpful tools are provided to the engineer to aide in the design, which has already been purchased by the Biomedical Engineering department. These include simulation software, an evaluation board, and an emulator. Before the processor is even programmed, VisualDSP++ software will be used to simulate the behavior of the DSP chip. Using this software we will be able to build, edit, and debug our DSP program before we even have the actual processor, which is done solely on the computer. After the simulation is complete, evaluation of the simulation is performed using the EZ-KIT Lite evaluation system to determine the specific Blackfin processor that fits our needs. This board (Fig. 31)

connects up to the computer via a cable, allowing us to run our simulation program. After the evaluation process, the JTAG emulation board (Fig. 32) will be used to serially scan the I/O status of each pin on the device as well as control internal operations of the device. This hardware connects our PC to the actual process target board via a USB cable.

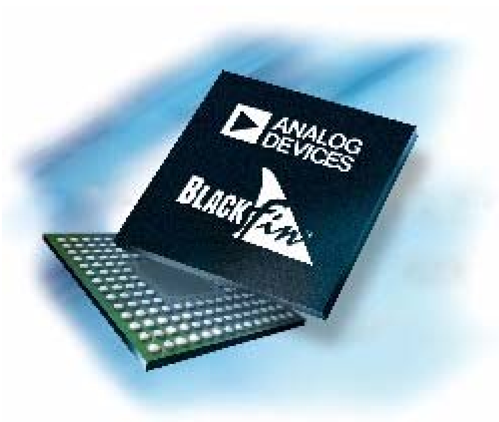
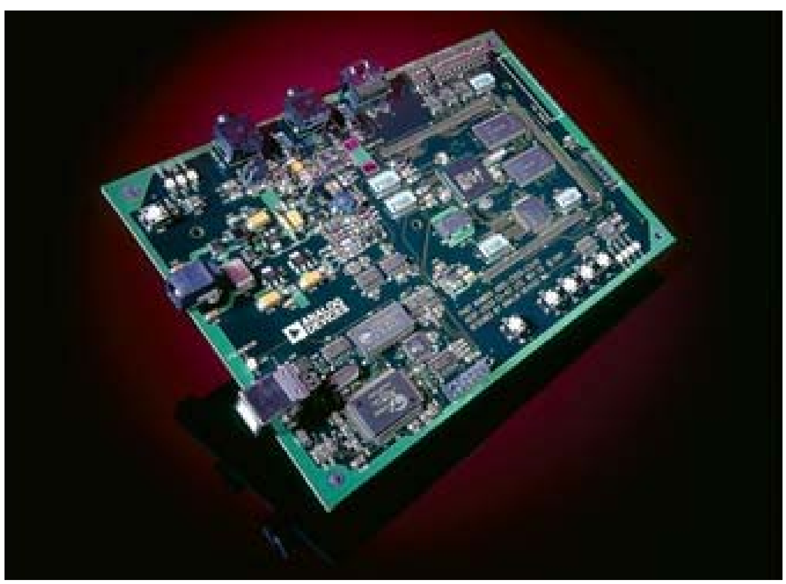


Figure 30. Blackfin Image

Table 1. Blackfin Specifications

Blackfin Specifications	
Clock Speed (MHz)	350MHz
MMACS (MAX)	700
RAM Memory (Kbytes)	308
External Memory Bus	32bit
Parallel Periph Interface	No
PCI	Yes
USB Device	Yes
UARTs, Timers	Yes
Watchdog Timer, RTC	Yes
Core Voltage (V)	1.0-1.6
Core Voltage Regulation	No
Package	260 PBGA



http://www.analog.com/images/Product_Descriptions/604755422433063415587000113339bf535_hardware.jpg

Figure 31. EZ-Kit Lite Evaluation Board

http://www.analog.com/images/Product_Descriptions/30502391903402849118416824438334027445629891175 00usb_emulator.jpg

Figure 32. JTAG Emulation

Like the traditional PIC Microchip, the Blackfin ADSP-BF535 processor contains timers, which may be used to pulse the LEDs on our pulse oximeter. This Blackfin contains 4 programmable timer units, but only 3 of which are general-purpose timers which we will use. The general-purpose timers can generate interrupts to the processor core providing periodic events for synchronization, either to the processor clock or to a count of external signals [3]**.** Since our LEDs will function as an external signal, this general-purpose timer can be used in assisting the pulsing of our pulse oximeter. The general-purpose pins are designated TMR0, TMR1, and TMR2. The timing requirements for the ADSP-BF535 processor clocks are shown in the table below (Table 2).

Table 2. Core Clock Requirements

Parameter		**Min**	**Max**	**Unit**
tCCLK1.6	Core Cycye Period (VDDINT=1.6V-50 mV)	2.86	200	ns
tCCLK1.5	Core Cycye Period (VDDINT=1.5V-5%)	3.33	200	ns
tCCLK1.4	Core Cycye Period (VDDINT=1.4V-5%)	3.7	200	ns
tCCLK1.3	Core Cycye Period (VDDINT=1.3V-5%)	4.17	200	ns
tCCLK1.2	Core Cycye Period (VDDINT=1.2V-5%)	4.76	200	ns
tCCLK1.1	Core Cycye Period (VDDINT=1.1V-5%)	5.56	200	ns
tCCLK1.0	Core Cycye Period (VDDINT=1.0V-5%)	6.67	200	ns
Operating Voltage		1.425	1.575	V

2.2.2.7 LCD Screens

The digital information from the output of the microcontroller will be sent to six character LCD screens (Fig. 33).

http://www.crystalfontz.com/products/1602l/CFAH1602L-YYH-JP_front_bl_on.jpg
Figure 33. LCD Screen

The CFAH1602L-GGH-JP LCD screens are ideal for our design due to its easy to read characters, ideal size, and wide viewing angles. It measures 122mm x 44mm, with a viewing area of 99mm x 24mm, and a character height of 8.06mm. These LCD screens were chosen due to the fact that many of the features meet the specific needs of our clients. Since the majority of our clients will be viewing the monitor from their bed, it is important that the screens should be viewable from a wide variety of angles. Since these screens have a wide viewing angle, patients will have no problem seeing their vital signs from their bed. Also, the yellow backlight makes this LCD screen easy to read, especially in dark or dim-lighted areas. Also, a viewing area of 99mm x 24mm makes the screens easy to read from a distance.

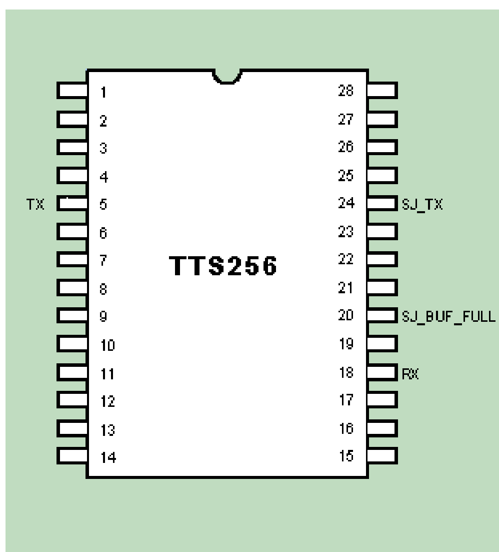
2.2.2.8 Speech Output

Our vital signs monitor will contain a text-to-speech function which will allow the monitor to say what the vital signs are once they have been recorded. This function will be useful for our client Mat, who is blind and cannot see the monitor. Even though his wife is around to help him, she is also vision-impaired. The output text from each pin on the microcontroller will need to be converted to sound. To do this, we will use the Magnevation SpeakJet IC (Fig. 34). It is an 18 pin IC which uses a mathematical sound algorithm to control an internal five channel sound synthesizer to produce sound. The SpeakJet can be controlled by a single I/O line from the Blackfin [13]. Since this microchip requires phonetics and not text, the TTS256 Text to Code IC will have to be used in conjunction with the SpeakJet. The TTS256 is an 8-bit microprocessor programmed with letter-to-sound rules. This built-in algorithm allows for the automatic real-time translation of English ASCII characters into allophone addresses compatible with the Magnevation SpeakJet Speech Synthesizer IC. This IC is Compatible with Basic Stamp, OOPic, Pic and any processor with a serial port, like our microchip [13]. We will use pin #5 (TX) to output the phonetics from the SpeakJet, and pin #18 (RX) to receive the data from the Blackfin (Fig. 35). The pin diagram of the TTS256 is shown below. The final sound will be sent from the Voice Output pin (#18) of the SpeakJet using +5V and a speaker. Since the SpeakJet is preconfigured with 72 speech elements, 43 sound effects, and 12 DTMF touch tones, we will also use the SpeakJet to produce an alarm when the vital signs are out of range (range to be determined). This chip will be tested

experimentally by providing to it a series of inputs to confirm that it is giving the correct outputs.

http://www.speechchips.com/images/SpeakJetIC.jpg

Figure 34. SpeakJet IC



http://www.speechchips.com/images/tts256.gif

Figure 35. Pin Diagram of TTS256

To play these computer generated sounds, a speaker from Futurelec (Fig. 36) will be purchased and attached to the microcontroller. This speaker was chosen due to its small size and affordable price. This speaker will be used to play the data output from the

microprocessor, as well as sound an alarm when the patients' vital signs become irregular.

http://www.futurlec.com/Pictures/Sm_Speaker.jpg

Figure 36. Small Speaker for Audio Output

Features
• Small Size
• Power rating: 0.5W
• Impedance: 8 ohm
• Dimensions: 50mm Diameter, 16mm High, 28mm base diameter

2.2.2.9 Alarm

To assist our clients, we will install an alarm system to alert them when their vital signs have become irregular or dangerous. On top of the monitor will sit a light that will flash when these signs become abnormal. A light we have chosen is shown below (Fig. 37). In addition, an alarm sound generated by the SpeakJet will also serve as an alert. The majority of the alarm design will be done by programming the microprocessor. We will have a set of defined limits for each vital sign, and if these signs fall out of range, a signal from the microcontroller will be sent to the SpeakJet and alarm light. The alarm lights will be tested by checking what the manufacturer recommended voltage to run them at is and then confirming that experimentally. Test values will be sent to the microprocessor to confirm the activation of the alarm over the programmed range. These values will be acquired by applying the known voltage for them to the microprocessor I/O pin that would normally receive them. For example, if we know that a voltage of .6V from the thermometer circuit is equivalent to a body temperature of 92°F, and that value is in our alarm range, we will apply .6V to the thermometer I/O pin of the microprocessor to see if the alarm activates as it should.

http://img.alibaba.com/photo/50538513/Alarm_Lights__Warning_Lights_.jpg
Figure 37. Alarm Light

2.2.2.10 Secure Website

After the patient's vital signs have been gathered and recorded, they need to be sent to their primary healthcare provider. To maximize patient privacy we have devised a way to securely transmit the patients' health information, minimizing the risk of interception. We will create an encrypted, password protected website to which the patient uploads the information from their USB stick. To ensure that the website is secure, HTML encryption software will be used to encrypt the contents of the website, allowing only those with the correct username and password to access it. We will use encryption software such as TagsLock Pro v 2.22 to hide the source code of our HTML documents. To encrypt HTML using TagsLock PRO, you need to create a new project once, and re-use it later when the site content gets modified and needs re-uploading. In order to use this encryption software, a website using the UCONN Biomedical Engineering server will have to be created for the prototype accessible home vital signs monitoring system

2.2.2.11 Power Supply

When designing this project we found it rather important to include two different types of power. The device will mainly be run from an external power source by using a power cord. It will also be equipped with rechargeable backup batteries in case of a power failure. For the power supply we plan on using a very generic universal power cord, which will plug into the back of our device and then also plug into the wall. For the backup power supply, we determined the best way would be to use nickel cadmium rechargeable batteries. Although lead acid batteries can sometimes produce more voltage, nickel cadmium batteries are safer and will recharge quicker. The need for a backup battery is so the patient can take their vital signs even if the power is gone.

Regarding the power source, it will be in charge of taking power from an outlet in a wall and transferring that power into our system. The type of power cord that we need to buy is a very basic cord, which will change the A/C power supply from the wall into the D/C power supply we need to power the device. From there, we will still have too much voltage and our machine will burn out. To bring down the voltage levels, the best possible way is to use linear voltage regulator (Fig. 38). The regulator we have decided to use is the AIC1086. It is a low drop regulator with 1.5A current output capability. This regulator will take in voltage from the power source and output a predetermined voltage of 2.85V, 3.3V, or 5V. Before and after the linear voltage regulator capacitors

are needed to act as a filter. None of our transducers should require more than 5 volts. These regulators are also very inexpensive at only around a couple of dollars each.

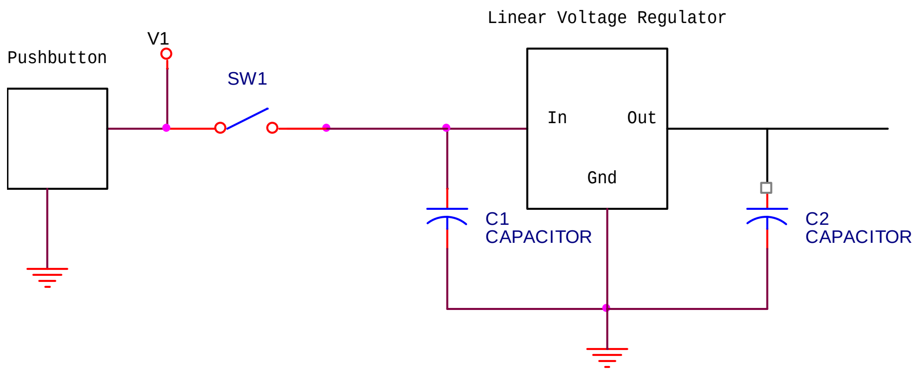


Figure 38. Voltage Regulator Circuit

2.2.2.12 USB Device

The USB device is a very important part to include in this project. The main job of the USB device is to store the readings taken by the vital signs monitor. This device will then be connected to a computer in which it is possible to send the readings to any computer that has an Internet connection. The USB device that we have decided to use is the Philips PDIUSBD12. The price of this device is only around $4.00. The PDIUSBD12 is a chip that will connect the microcontroller to the USB port. This device uses parallel technology to connect to the microcontroller. For the rest of the project, a Blackfin will be used as the main microprocessor for the device. For the PDIUSBD12 an additional microcontroller is needed to make it easier to connect with the chip. The microcontroller we chose is the PIC16F874. This allows for easy communication between the two chips. By writing a computer program in the microcontroller we will be able to send the data received by the vital signs monitor to the USB device and then to the computer. The following image shows the schematic of a how the USB device will connect with the microcontroller (Fig. 39).

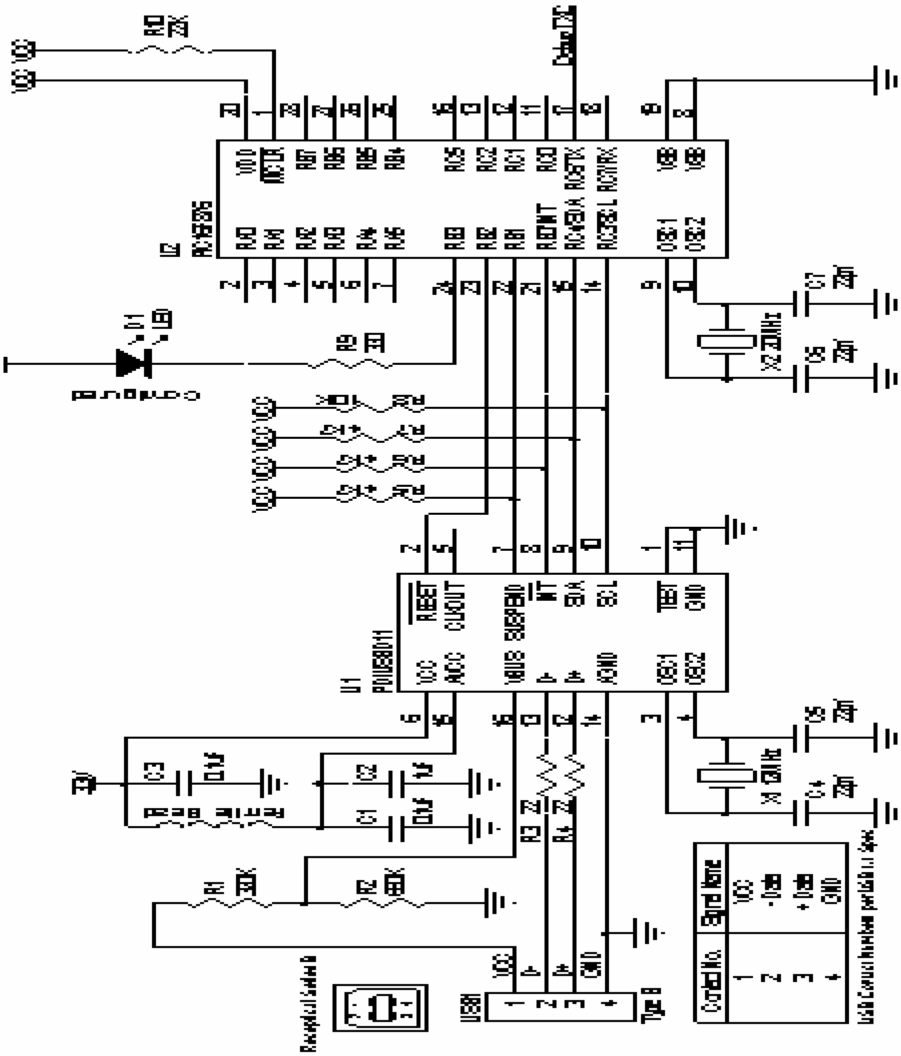


Figure. 39 USB Schematic

2.2.2.13 Bluetooth

To increase accessibility, we will add a Bluetooth option to transmit the data collected by the vital signs monitor to the client's computer wirelessly. This will be in addition to the USB port. We will purchase the EmbeddedBlue eb100-SER OEM Bluetooth Serial Module from A7 Engineering for $40 to integrate into our vital signs monitor to provide Bluetooth connectivity (Fig. 40).

Figure 40. EmbeddedBlue eb100-SER OEM Bluetooth Serial Module

This module contains all the components of the Bluetooth stack on the board so that no additional host processor code is needed. The interface between our host processor and the eb100-SER radio will be done through UART communication. When a connection is made to another Bluetooth device, the link will appear as a cabled serial connection which eliminates the need for any special wireless protocol knowledge. Assuming that our clients' computers are not Bluetooth ready, a USB Bluetooth dongle will be purchased (usually at $10-$20) to provide connectivity on the PC end. These USB dongles are easy to use and come with software to install on the PC to allow Bluetooth connectivity.

Bluetooth communicates data via low-power radio waves on the 2.4 GHz frequency. This is the ISM frequency band. It has been internationally agreed upon to be used only for industrial, scientific, and medical devices (ISM). Many devices make use of the ISM band, but Bluetooth has precautions in place to prevent interference with these other systems, making it and ideal technology for our use. One way in which Bluetooth prevents interference is by only sending out very weak signals (of about 1 milliwatt). This limits Bluetooth's range to about 10m (although advances in the technology have made it possible for transmission ranges up to 100m). This is an acceptable range considering that our device is meant only for home use. However, because of this, we do advise that users ensure they are within a 10 m radius of their computer when using their vital signs monitor. Another way in which Bluetooth limits interference is through frequency hopping. This also helps ensure the security of the data being transmitted. Bluetooth transmitters use 79 randomly chosen frequencies and "hop" between them 1,600 times per second.

Our Bluetooth communications system will be calibrated through UART communication with any extra equipment necessary provided by the BME 252 lab. It will be programmed to set up a network with the Bluetooth USB dongle when it detects it. The Bluetooth system will be tested by acquiring vitals signs from the monitor and sending them to a computer in the design lab to which the USB dongle is installed. The vital signs monitor will be placed at different ranges within 10 meters to determine signal strength at different ranges and the optimum range for data transmission.

2.2.2.14 Pushbuttons

Along with our design we decided one of our most important features was going to be the buttons that were involved. We need to have our buttons customizable so we can include a universal sign and also Braille so they can be used by people vision

impairment. After searching for a while, we determined that there were not many sites which made this option available, but we did find one called http://www.grayhill.com/pushbuttons. Through this site, it is possible to determine the option of your pushbuttons including a Braille option. We will also be able to choose what colors we want the buttons to be. The model button that will fit our project the best is a rectangular button that is about 15 by 20 millimeters in size. These buttons are very easy to secure by a short, simple process.

The buttons require a proper size hole to be drilled in the area where the buttons will be placed. The buttons will then be snapped into the whole. Once the button is snapped into the hole, it has wings that will then open causing the button to not be removed. The only visible problem with this product is that the button may be too small. The buttons seem to cost around $10 but could be more depending on if the customization of the buttons raises the price. Connecting either choice of button to our main circuit does not really require a lot of work. Our buttons are basically going to act like a switch either turning the power on or off. The start button will be connected to the beginning of the circuit. There will be a switch in the circuit that will either be open if the circuit is not working or closed if power is to be given to the entire circuit. When the start button is pressed, the switch on the circuit will close allowing for the power supply to be sent to and power the rest of the circuit. When the patient feels the process is complete they will be able to press the stop button, which will allow for the circuit to open disallowing any power to get through to the circuit. The button is a two-probe button. One probe will be attached to the circuit by a switch and the other probe will be attached to the ground.

2.2.2.15 Casing

In order to safely enclose the internal circuitry of our design, a plastic enclosure needs to be manufactured. We will use the company Toolless Plastic Solutions to manufacture our casing. In order for this company to manufacture our case, we need to submit an AutoCad™ drawing of the final casing design. Preliminary AutoCad™ drawings of the casing can be seen in Figs 41 and 42. Since we will not know the exact size and placement of all 6 holes for the LCD screens, and the various I/O ports in the casing, the design will be submitted in the spring semester when all the parts have been ordered and more about the final design is known. Toolless Plastic Solutions requires no tooling or molds, and therefore will be a cost-effective way to obtain an enclosure for our design [7]. The company uses CNC (Computer Numerical Control) machining and fabrication process to build plastic casings. We will not know the exact price of the casing until a design is sent for a quote.

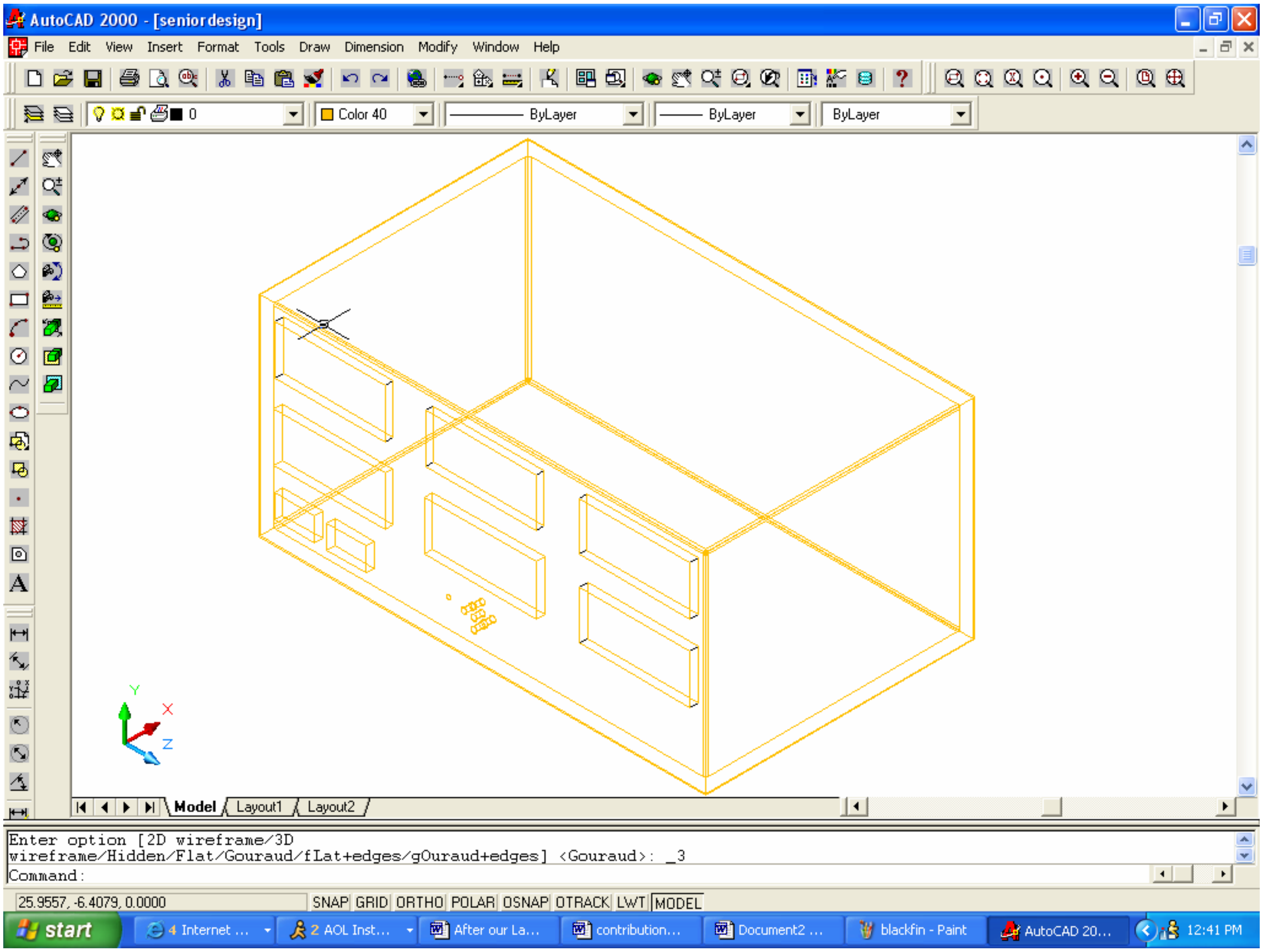


Figure 41. Preliminary AutoCad™ Skeleton of Casing

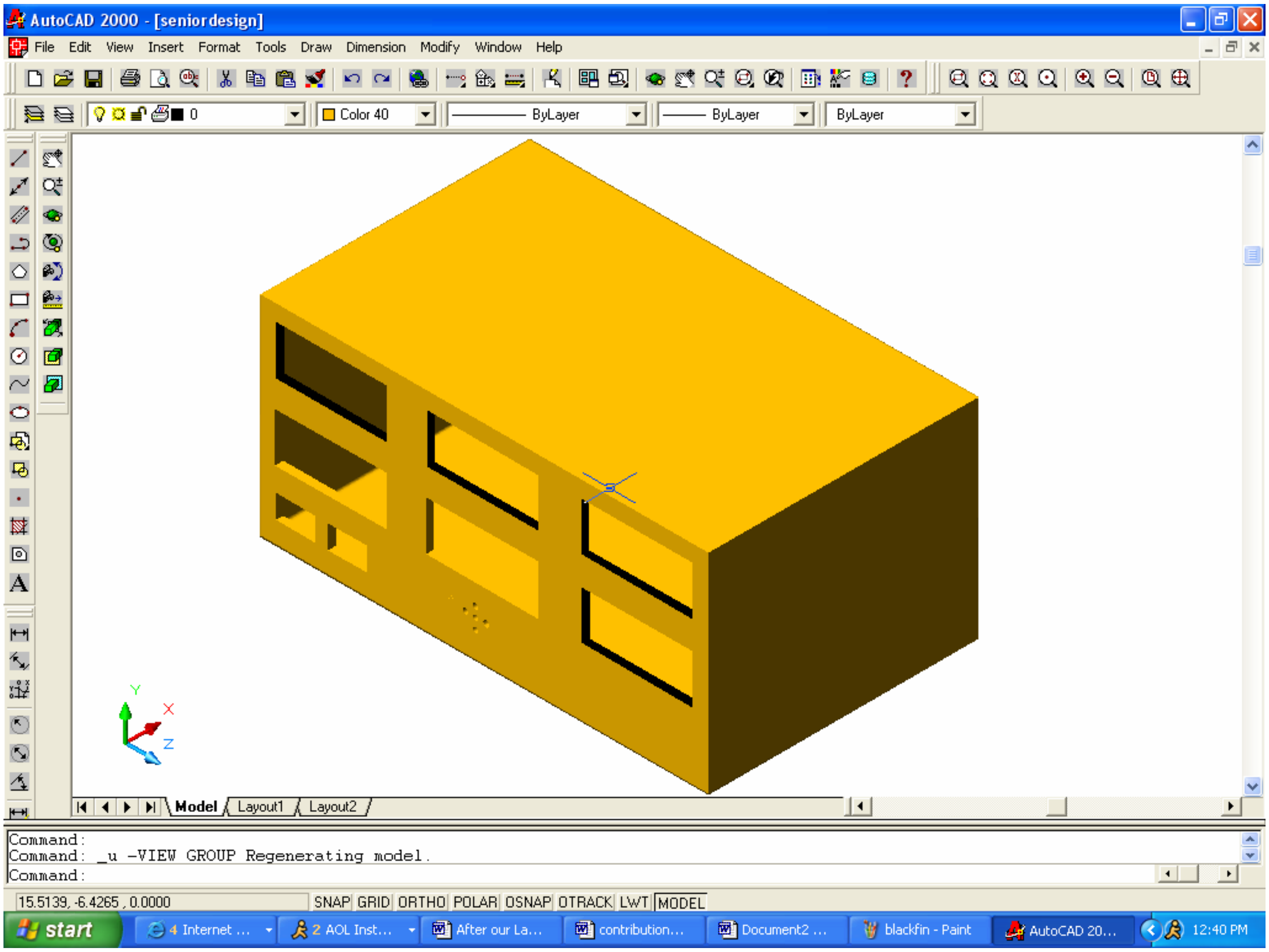


Figure 42. Preliminary AutoCad™ Illustration of Casing

2.2 .2.16 Accessible Vital Signs Monitor Circuit Diagram

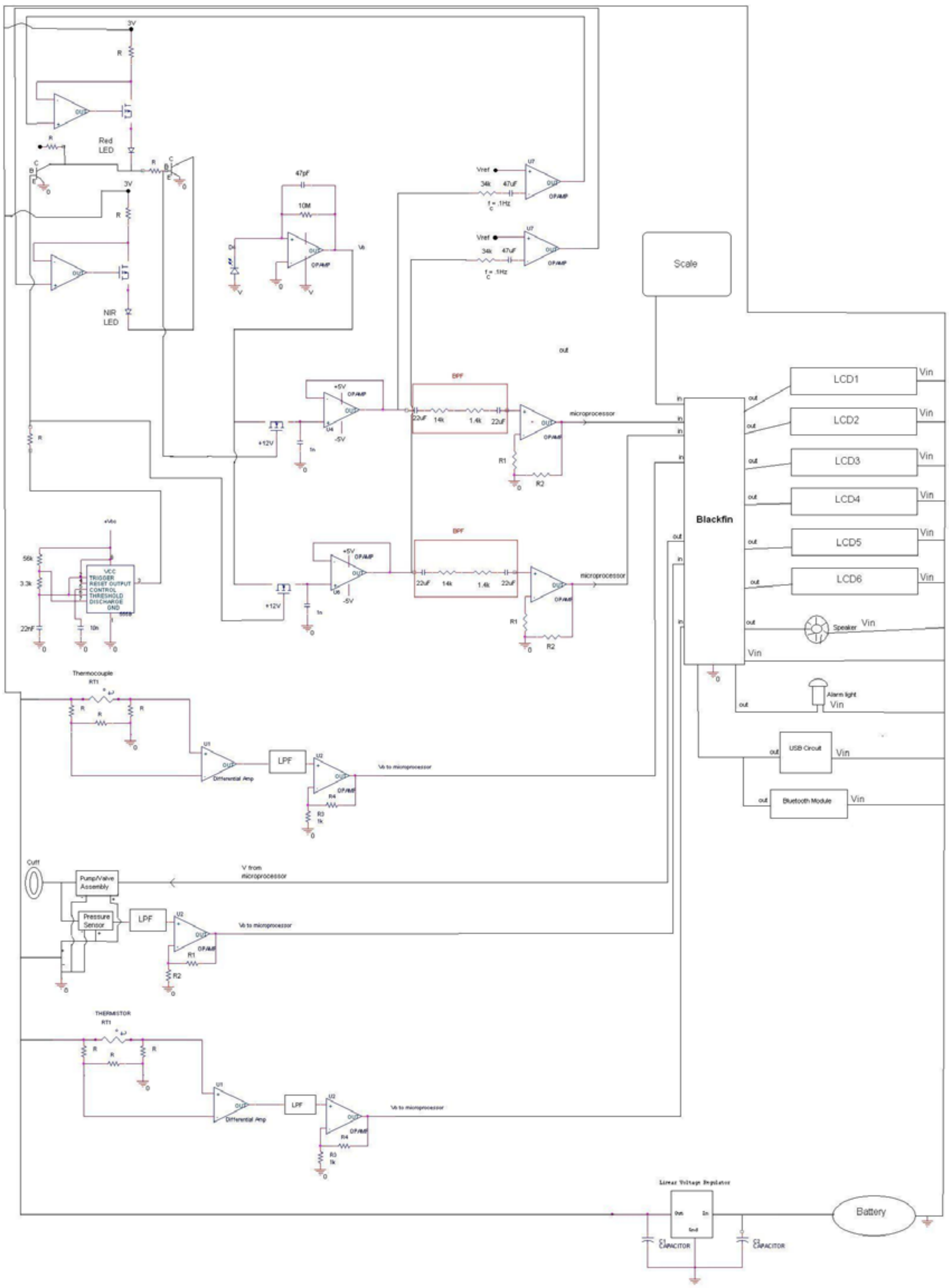


Figure 43. Accessible Vital Signs Monitor Circuit Diagram

The previous figure combines all of the above subunits into a circuit diagram. This is a basic diagram of our complete vital signs monitor (Fig. 43).

3 Realistic Constraints

The main source for medical instrumentation standards is the Association for the Advancement of Medical Instrumentation (AAMI). They provide for purchase the current standards of medical device design and use. These standards must be followed in the design and production of our device to ensure that it is acceptable and safe for our clients and the health care community.

This device has been designed with the economic constraint of cost in mind. We have a maximum budget of $2000 to build a working prototype of our device, so parts were chosen carefully. A balance had to be maintained between using parts that meet the needs of our design and not overspending our budget. It may be especially important to have room left in our budget next semester when we begin the actual construction of our device. We may need to order replacement parts or additional parts as we go and we cannot do that if we have no money left within our budget.

Our accessible home vital signs monitor is meant for use in the home, so varying environmental conditions are not a large concern of the device. However, being used in the home, there were a few things we needed to keep in mind as we made our design. Our device will be exposed to dust, sunlight, food, and water. Though it is not meant to withstand an onslaught of any of these things, it was designed to be relatively robust in these conditions. No parts were used that are very sensitive to movement or other household factors that could affect their use. The device will have a durable plastic casing has been designed to withstand the typical rigors of home electronic life (movement, animals, children, cleaning, spills, etc.). That being said, the device is not a toy, nor was it designed to be one, and the user should keep in mind the device's purpose when using it. There are little to no concerns over our device's effect on the environment. As it is a piece of home electronics, it has very little effect on the environment as a whole.

Offshoots of the environmental constraints laid on our device are the accessibility constraints that it needs to meet. Our device was designed to be properly accessible so that it will be of use to our clients and meet their needs. Audio and visual output, along with Braille and raised universal symbols were used to make the device user friendly to anyone with vision or hearing impairment. Also, the simple user interface of the device allows it to be used by individuals of all ages and technological savvy.

This leads into sustainability. Our device was designed with its ability for future and continued use in mind. Not only must the device be designed so that it can last and function properly for years, but it also needs to use up-to-date parts and technology so that it does not become outmoded. An example of this was the selection of the rechargeable battery for our device. In many vital signs monitors being used, rechargeable lead batteries power the device. However, lead materials are currently being phased out of medical devices so we chose to use a nickel cadmium rechargeable battery in our design. This is one step that was taken to ensure that our device will still be acceptable for use years from now.

Because this is a medical device and will have direct contact with our clients, client/patient safety was an important constraint in our design process. All circuits and power sources must be properly grounded to prevent accidental electrocution and safety measures had to be put in place to prevent an injury use of the device might cause. Since

this is a medical monitoring device, one of its safety constraints is that it should not be explosive. It should not spark or create flames, which could cause an explosion when used in the presence of pure oxygen. Most components of our design are relatively benign (provided that basic electrical safety is followed), but a major point of health and safety constraint was the design and incorporation of the automatic blood pressure measuring device. Self-inflating blood pressure cuffs can cause injury if not properly calibrated and used (Fig. 44).

Figure 44. Bruising Caused by One Use of an Automatic Blood Pressure Cuff [15].

Bruising can result if the cuff inflates too much. Pain and circulation cutoff can occur if the cuff does not deflate, and at the extreme this could lead to tissue death.

Our accessible vitals signs monitoring system has really no political constraints, but it does have social and privacy constraints. Part of our system includes the transmission of vitals signs of the internet to a health care provider. To protect patient privacy and abide by the Health Insurance Portability and Accountability Act (HIPAA), the transmission of vital signs will be done via a secure, password protected website. This will protect our clients' personal information while still giving them flexibility in the transmission of their vital signs to their physicians or HMOs. This is an important and valid constraint in our device design. The internet provides rapid transfer of information, but it is filled with predators and opportunists who like to access the private information of others. It is important for us to protect our clients when they are contacting their physicians so that their medical information does not end up all over the World Wide Web.

By paying heed to these constraints and working with them, not around them, our accessible home vital signs monitoring system has been designed with the best interests of our clients and society at heart. This ensures that we have designed an economically

feasible device, affordable for our clients. Our device is appropriately designed for the environment which it will be used in, and with careful part selection it will sustain and continue to be appropriate for the home monitoring of vital signs.

4 Safety Issues

Safety plays a crucial role when designing a product, especially one that contains electrical components. Because our design will be comprised mainly of electrical components, we have strived to effectively enclose the inner circuitry of our final design with a durable, non-conductive, completely closed casing. The casing of our final design will show no wires, circuit boards, or any part of the inner circuitry. Loose wires have the potential to not only cause the device to operate ineffectively, but they could also be hazardous to the patient. Any moisture from the air, or water accidentally spilled near the device, could cause a spark and start a small fire. It is for this reason that it will be recommended that all liquids be kept off of and way from the monitor, regardless of how good the casing. Also, it is important for the casing to be made of a non-conductive material (such as plastic), so that if the “hot” side of the power system touches the side of a casing, there is no danger to the user of the monitor. The inner part of the monitor should be designed so that neither the “hot” or “neutral” part of the power cord touches the casing. If the casing were conductive and the “hot” wire touches the side of the case, then the case would be made electrically common to the wire and touching the case would be just as hazardous as touching the bare wire.

In addition, it is always important for an electrical design to have a solid connection to earth ground. A power system with no secure connection to earth ground could pose a safety hazard. There is no way to guarantee how much or how little voltage will exist between any point in the circuit and earth ground. By grounding one side of the power system's voltage source, at least one point in the circuit can be assured to present no shock hazard. One way to ensure proper ground is to use a three-prong plug. The third prong on the power cord provides a direct electrical connection from the appliance case to earth ground, making the two points electrically common with each other. If they are electrically common, then there cannot be any voltage dropped between them. Even if the “hot” wire accidentally touches the metal casing, it will create a direct short-circuit back to the voltage source through the ground wire. The patient’s skin plays an important resistive role in protecting the body from such hazards. But when the skin becomes wet or broken, this resistive value drops to 1% of its original value putting the patient in serious harm if electrical safety precautions are not followed correctly [1]. A circuit that is not properly grounded will have the potential to cause microshock. Microshock is defined as the passing of high current from one body part to another, such as from arm to arm and therefore directly through the heart. Such high doses of current can cause difficulty breathing, and even ventricular fibrillation [1].

Choosing the correct gauge wire is also an important factor to consider. An electrical hazard exists when the wire is too small a gauge for the current it will carry. If a wire is too small for the current it is supposed to carry, the wire will heat up. The heated wire could have the potential to cause a fire inside the monitor. After selecting the correct wire gauge, it is important to make sure that all wires are properly insulated and cleanly soldered to their respective positions on the circuit board. Frayed wires have the

potential to interact with other wires causing the monitor to not work properly or starting a fire.

In addition to the electrical safety issues, it was also made sure that the operator of the monitor does no harm to the patient while taking measurements. Each instrument used to obtain measurements was carefully chosen to be as simple and safe as possible. Out of the four vital signs being obtained, the only one which requires any skill to operate is blood pressure. Using the blood pressure cuff incorrectly could not only cause the monitor to record the wrong vital signs, but also harm the patient. Squeezing the blood pressure cuff too tightly could injure the patient. To minimize this potential hazard, we will use an automatic blood pressure cuff, allowing the person who is taking the readings to have no prior skill. Since the people taking the vital sign readings may be elderly, young or physically impaired, the automatic blood pressure cuff makes gathering data relatively simple. Even though the automatic blood pressure cuff is simple to use, it is still not completely foolproof.

5 Impact of Engineering Solutions

Much of the technology used in our design for an accessible home vital signs monitoring system is not new, but the manner in which it is being employed is valuable. There are few, if any, accessible vital sign monitors currently available. Patent and web searches have not revealed devices on the market comparable in that regard to the device that we have designed. The design of an accessible vital signs monitor will improve the quality of life for those individuals with hearing and vision impairment who need to have their vital signs monitored. This device will allow those individuals the ability to go home to recuperate while still being effectively monitored by their health care provider. This is especially important in cases where home health care would be a treatment option for someone without visual or hearing impairments but not for someone with them.

Home health care is a growing industry. Approximately 7.6 million individuals receive home care in the United States. The Center for Disease Control reported that in the United States in 2000, 317,600 individuals in home care were using medical devices (Fig. 45).

Medical							
Total with medical devices	317,600	15,900	31,700	58,300	74,300	84,800	52,600
Blood glucose monitor	132,500	*	11,800	19,200	38,600	37,300	25,000
Enteral feeding	30,700	*	*	*	*	*	*
Intravenous therapy	52,300	*	17,100	*	*	*	*
Oxygen[6]	114,600	*	*	18,200	25,700	43,400	19,900
Other respiratory therapy	45,300	*	*	*15,000	*	*	*
Other aids	187,500	11,600	23,600	33,100	28,200	58,600	32,400

* Figure does not meet standard of reliability or precision because the sample size is less than 30 if shown without an estimate. If shown with an estimate, the sample size is between 30 and 59, or the sample size is greater than 59 but has a relative standard error of 30 percent or more.

- Quantity zero.

[1] Age is the patient's age at the time of survey.

[2] Numbers will not add to totals because a patient may be included in more than one category.

[3] Total number of home health care patients.

[4] Includes manual and motorized wheelchairs.

[5] Includes geri-chairs, lift chairs, and other specialized chairs.

[6] Includes oxygen concentrator.

Figure 45. Excerpt from Table of Number of Current Home Heath Care Patients with Aides and Devices in 2000 [12].

As such, it is important to have reliable technology to support home care. Home care can not only save patients and insurance companies money (Fig. 46), but living at home can provide patients a welcome and comfortable environment in which to recover and be monitored.

Table 18. Cost of Inpatient Care Compared to Home Care, Selected Conditions

Conditions	Per-patient Per-month Hospital Costs	Per-patient Per-month Home Care Costs	Per-patient Per-month Dollar Savings
Low birth weight[1]	$26,190	$330	$25,860
Ventilator-dependent adults[2]	21,570	7,050	14,520
Oxygen-dependent children[3]	12,090	5,250	6,840
Chemotherapy for children with cancer[4]	68,870	55,950	13,920
Congestive heart failure among the elderly[5]	1,758	1,605	153
Intravenous antibiotic therapy for cellulitis, Osteomyelitis, others[6]	12,510	4,650	7,860

Sources: [1]Casiro, O.G., McKenzie, M.E., McFayden, L., Shapiro, C., Seshia M.M.K., MacDonald, N., Moffat, M., and Cheang, M.S. "Earlier Discharge with Community-based Intervention for Low Birth Weight Infants: A Randomized Trial." *Pediatrics* 92, no. 1 (1993): 128-134.
[2]Bach, J.R., Intinola, P., Alba, A.S., and Holland, I.E. "The Ventilator-assisted Individual: Cost Analysis of Institutionalization vs. Rehabilitation and In-home Management." *Chest* 101, no. 1 (1992): 26-30.
[3]Field, A.I., Rosenblatt, A., Pollack, M.M., and Kaufman, J. "Home Care Cost-Effectiveness for Respiratory Technology-dependent Children." *American Journal of Diseases of Children* 145 (1991): 729-733.
[4]Close, P., Burkey, E., Kazak, A., Danz, P., and Lange, B. "A Prospective Controlled Evaluation of Home Chemotherapy for Children with Cancer." *Pediatrics* 95, no. 6 (1995): 896-900. (**Note**: The study found that the daily charges for chemotherapy were $2,329±$627 in the hospital and $1,865±$833 at home. These charges were multiplied by 30 days reflecting the above per-patient per-month costs.)
[5]Rich, M.W., Beckham, V., Wittenberg, C., Leven, C., Freedland, K., and Carney, R.M. "A Multidisciplinary Intervention to Prevent the Readmission of Elderly Patients with Congestive Heart Failure." *The New England Journal of Medicine* 333, no. 18 (1995): 1190-1195.
[6]William, D.N., et al. "Safety, Efficacy, and Cost Savings in an Outpatient Intravenous Antibiotic Program." *Clinical Therapy* 15 (1993): 169-179, cited in Williams, D., "Reducing Costs and Hospital Stay for Pneumonia with Home Intravenous Cefotaxime Treatment: Results with a Computerized Ambulatory Drug Delivery System." *The American Journal of Medicine* 97, no. 2A (1994): 50-55. (**Note**: The estimated hospital cost/day/patient is $417 and the estimated savings/day/patient is $262. These costs were multiplied by 30 days, reflecting the above per-patient per-month costs.)

Figure 46. Table of Home Care Cost Savings [2].

When patients choose (or have the option) to enter home care, they free up hospital beds for more acute cases, give doctors more time to work with sicker people, and many times the patients themselves are happier at home than in the hospital. But, patients cannot be cared for at home unless they have the proper technology to do so. Our accessible vital signs monitoring device is a simple, easy-to-use method to monitor patients' health at home. It can be operated by patients, their families, and physicians, making it an ideal device for the home environment. Since vitals signs are saved on a USB flashdrive to be uploaded to a secure website, patients are not even stuck at home, but can take their rechargeable battery powered vital signs monitor with them if they need to monitor their vital signs. This offers flexibility and comfort to patients.

Economically, the design for our device will reduce some of the costs of healthcare. Vitals sign monitors (and many of these are not accessible) currently range in cost from $2500 up to $5000. Most of the monitors that measure four of the same vitals

signs that our device does (heart rate, blood oxygen saturation, blood pressure, and temperature) cost closer to $5000. If a patient's health insurance will not cover this cost than it becomes a large out-of-pocket expense for them, or they may not be able to afford the device at all. This is detrimental to their health and recovery. By designing a monitor that's expected cost is $700 (a third of the cost of the cheapest monitors currently available), we will be able to alleviate some of this financial stress and provide more comprehensive health care and monitoring to more people.

Globally, this design may translate into an affordable piece of medical equipment for undeveloped countries. With its two-button user interface, detachable transducers, and simple design, it may be useful in countries with a low level of technology. Our device is designed for home use, but in countries and areas with poor healthcare systems and little to no medical equipment, it would be useful in a hospital or emergency room. Because it is lightweight and has a rechargeable battery, and because vital signs are saved onto a USB flashdrive, our accessible vital signs monitoring system is an excellent option for remotely monitoring patients in areas where there are few trained medical personnel. A layperson (with no medical training) could use our device to visit a patient who does not have access to a hospital or doctor and record their vitals signs on a USB flashdrive. These measurements could then be uploaded to the secure website and accessed by doctors anywhere.

6 Life-Long Learning

During the research of this design, we were introduced to new and challenging engineering applications. In updating our processing technique, we learned about the Blackfin and digital signal processing. Although we have already learned about FIR and IIR filters thus far in our engineering curriculum, we were now able to apply these concepts to a real life situation. Through researching digital signal processing we were able to compare it to traditional microcontroller design and see the differences. Digital signal processing is not only substantially faster, it also eliminates additional hardware associated with analog circuits. Although analog circuits are cheap and easy to assemble, software based DSPs provide flexibility in modification and maintenance. We learned to integrate microcontroller based data gathering with digital signal processing to achieve a cheaper, more efficient way of data analysis.

Also, the text-to-speech function in our design was a new and exciting function to learn about. Since none of us have ever worked with such a unique and advanced tool, it made the research enjoyable and informative. There are many devices out there used for speech synthesis, but we needed to find the one that would be compatible with the microcontroller we selected, as well as capable of converting the text output from the microcontroller to sound. Most algorithms associated with speech chips cannot convert English text straight to audio, which is why we integrated the TTS256 Text to Code microcontroller to convert text to phonetics, which is compatible with the SpeakJet.

Through designing the thermometer for the accessible vital signs monitor, we have learned about the Steinhart-Hart equation and the properties of thermistors. It is important to realize that thermistors behave nonlinearly and to understand what effects this has on designing a thermometer. In order to use the thermistor output, it must be linearized. This can be done over a small temperature range, but any readings outside the

temperature range will be increasingly inaccurate the farther away they are. This means that one should only use an oral thermometer to measure oral body temperature, not air temperature or a cold beverage.

We learned about the optical properties of blood and the Beer-Lambert law to design a pulse oximeter circuit. Also from the pulse oximeter, we saw the application of transistors to switching and timing. Research into an automated blood pressure measurement system highlighted the importance of control systems in medical devices. Even for something as seemingly benign as an automatic blood pressure cuff system, safety precautions have to be taken to ensure that a patient is not harmed through the use of the device. This design also required us to learn about pressure sensors, pressure release valves, and air pumps. Blood pressure waveforms were studied, and the oscillometric method for blood pressure measurement was introduced to us.

In addition to learning new technical engineering applications, senior design has also taught us to work and function as a group. By working as group, we learned to interact and communicate with each other to assess and resolve problems, as well as rely on each other to make deadlines. Since communication is an essential element of being an engineer, working on these skills before we graduate will give us an edge over the majority of graduating engineers. Whether we will be working with an engineering design team, a team of healthcare professionals, or in a corporate environment when we graduate, we will need to use these group skills we are currently developing to drive a successful career.

7 Budget and Timeline

7.1 Budget

Table 3: Design Budget

Part	Cost	Shipping and Handling
Snap-in Style Pushbutton (Mouser)	$103.20 for 3 ($34.40 each)	Unknown
AC/DC Power Converter (shop.com)	$29.95	$10.47
9V Rechargeable Battery	$17.64 for 3 ($5.88 each)	$6.49
Digital Scale (Homedics)	$19.95	$6.95
PIC Microprocessor	$5.84	Unknown
Philips USB Chip	$3.49	$6.41
Linear Voltage Regulator	$3.11	
Arm Cuff (CVS)	$9.99	N/A
Digital Thermometer (Vicks)	$11.99	N/A
CTS Single Head Micro Air Pump	$48.00	$9.18
MPX2200 Pressure Sensor (Digikey)	$12.76	$11.41
Crystalfontz LCD screens	$164.22 for 6 ($27.37 each)	$12.75
Blackfin Processor	$23.63	Unknown
Total: $517.43	$453.77	$63.66

7.2 Timeline

Table 4: Project Timeline (1-100)

ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		Order Parts	1 day	Tue 1/16/0	Tue 1/16/0		
2		Make thermometer probe	2 days	Wed 1/17/0	Thu 1/18/0		
3		Build thermometer circuit	1 day	Fri 1/19/07	Fri 1/19/07		
4		Test thermometer circuit	1 day	Mon 1/22/0	Mon 1/22/0	2,3	
5		Develop thermometer voltage curve	1 day	Tue 1/23/0	Tue 1/23/0	2,3,4	
6		Learn Blackfin software	28 days	Mon 12/18/0	Wed 1/24/0		
7		Blackfin development	12 days	Tue 1/16/0	Wed 1/31/0		
8		Build pulse oximeter probe	2 days	Fri 1/26/07	Mon 1/29/0		
9		Test pulse oximeter probe	1 day	Tue 1/30/0	Tue 1/30/0	8	
10		Build pulse oximeter driver circuits	0.5 days	Wed 1/31/0	Wed 1/31/0		
11		Test pulse oximeter driver circuits	0.5 days	Wed 1/31/0	Wed 1/31/0	10	
12		Build timer circuit	0.5 days	Fri 2/2/07	Fri 2/2/07		
13		Test timer circuit	0.5 days	Fri 2/2/07	Fri 2/2/07	12	
14		Build sample and hold circuits	0.5 days	Mon 2/5/07	Mon 2/5/07		
15		Test sample and hold circuits	0.5 days	Mon 2/5/07	Mon 2/5/07	14	
16		Complete pulse oximeter circuit	1 day	Wed 2/7/07	Wed 2/7/07		
17		Test pulse oximeter circuit	1 day	Fri 2/9/07	Fri 2/9/07		
18		Calibrate pulse oximeter	1 day	Mon 2/12/0	Mon 2/12/0	16	
19		Add LCD screens to Blackfin circuit	5 days	Fri 2/2/07	Thu 2/8/07		
20		Set up pump/valve assembly for BP circuit	0.5 days	Wed 2/14/0	Wed 2/14/0		
21		Test valve/pump assembly	0.5 days	Wed 2/14/0	Wed 2/14/0	20	
22		Build blood pressure circuit	1 day	Fri 2/16/07	Fri 2/16/07		
23		Test blood pressure circuit	2 days	Mon 2/19/0	Tue 2/20/0	22	
24		Test BP inflation control circuit ("kill switch")	2 days	Wed 2/21/0	Thu 2/22/0	23	
25		Experimental determine sys. and dias. threshold voltages	1 day	Wed 2/21/0	Wed 2/21/0	22	
26		Build respiratory rate probe	0.3 days	Fri 2/23/07	Fri 2/23/07		
27		Build respiratory rate circuit	0.3 days	Fri 2/23/07	Fri 2/23/07		
28		Test respiratory rate circuit	0.3 days	Fri 2/23/07	Fri 2/23/07	26,27	
29		Determine scale LCD screen connections	1 day	Fri 1/19/07	Fri 1/19/07		
30		Connect scale LCD output to Blackfin	1 day	Fri 1/26/07	Fri 1/26/07	29	
31		Test speech module	5 days	Fri 2/16/07	Thu 2/22/0		
32		Program speech module	3 days	Fri 2/23/07	Tue 2/27/0	31	
33		Connect speech module to Blackfin	2 days	Wed 2/28/0	Thu 3/1/07	31,32	
34		Add speaker to device	1 day	Fri 3/2/07	Fri 3/2/07		
35		Test speaker with speech module and Blackfin	1 day	Mon 3/12/0	Mon 3/12/0	34	
36		Build USB module	5 days	Mon 1/29/0	Fri 2/2/07		
37		Calibrate and Troubleshoot USB module	3 days	Mon 2/5/07	Wed 2/7/07	36	
38		Test USB Module	1 day	Fri 2/9/07	Fri 2/9/07		
39		Connect USB Module to Blackfin	3 days	Mon 2/12/0	Wed 2/14/0		
40		Write thermometer code for Blackfin	0.5 days	Mon 1/22/0	Mon 1/22/0		
41		Write pulse oximeter code for Blackfin	1 day?	Mon 2/12/0	Mon 2/12/0		
42		Write heart rate code for Blackfin	3 days?	Wed 2/14/0	Fri 2/16/07		
43		Write blood pressure code for Blackfin	5 days?	Wed 2/21/0	Tue 2/27/0		
44		Write respiratory rate code for Blackfin	1 day?	Wed 2/28/0	Wed 2/28/0		
45		Write scale code for Blackfin	0.5 days	Mon 1/29/0	Mon 1/29/0		
46		Build voltage regulator circuits	1 day	Fri 2/16/07	Fri 2/16/07		
47		Set up device power source (A/C jack)	2 days	Fri 2/16/07	Mon 2/19/0		
48		Build recharge circuit	5 days	Mon 2/19/0	Fri 2/23/07		
49		Test recharge circuit	2 days	Mon 2/26/0	Tue 2/27/0	48	

ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
50		Test Bluetooth module	3 days	Mon 2/26/0	Wed 2/28/0		
51		Write code for Bluetooth module	2 days	Fri 3/2/07	Mon 3/5/07		
52		Test Bluetooth dongle	1 day?	Mon 3/12/0	Mon 3/12/0		
53		Test complete Bluetooth system for device	3 days	Wed 3/14/0	Fri 3/16/07		
54		Build cohesive vital signs monitor	5 days	Fri 3/16/07	Thu 3/22/0		
55		PCB design	18 days	Thu 3/1/07	Mon 3/26/0		
56		Order PCB	1 day?	Tue 3/27/0	Tue 3/27/0	55	
57		Case design	18 days	Thu 3/1/07	Mon 3/26/0		
58		Order case	1 day	Tue 3/27/0	Tue 3/27/0	57	
59		Research alarm parameters	5 days	Mon 1/1/07	Fri 1/5/07		
60		Write alarm code for Blackfin	3 days	Thu 2/1/07	Mon 2/5/07		
61		Solder parts to PCB	5 days	Fri 4/6/07	Thu 4/12/0	56	
62		Put vital signs monitor together with casing and transduce	5 days	Fri 4/13/07	Thu 4/19/0		
63		Test completed vital signs monitoring system	1 day	Fri 4/20/07	Fri 4/20/07		
64		Develop secure website	25 days?	Mon 2/26/0	Fri 3/30/07		
65		Test secure website	1 day?	Mon 4/2/07	Mon 4/2/07	64	
66		Add button switches to appropriate circuits	1 day?	Fri 3/16/07	Fri 3/16/07		
67		Update Website Week 1	1 day?	Fri 1/19/07	Fri 1/19/07		
68		Update Website Week 2	1 day?	Fri 1/26/07	Fri 1/26/07		
69		Update Website Week 3	1 day?	Fri 2/2/07	Fri 2/2/07		
70		Update Website Week 4	1 day?	Fri 2/9/07	Fri 2/9/07		
71		Update Website Week 5	1 day?	Fri 2/16/07	Fri 2/16/07		
72		Update Website Week 6	1 day?	Fri 2/23/07	Fri 2/23/07		
73		Update Website Week 7	1 day?	Fri 3/2/07	Fri 3/2/07		
74		Update Website Week 8	1 day?	Fri 3/16/07	Fri 3/16/07		
75		Update Website Week 9	1 day?	Fri 3/23/07	Fri 3/23/07		
76		Update Website Week 10	1 day?	Fri 3/30/07	Fri 3/30/07		
77		Update Website Week 11	1 day?	Fri 4/6/07	Fri 4/6/07		
78		Update Website Week 12	1 day?	Fri 4/13/07	Fri 4/13/07		
79		Update Website Week 13	1 day?	Fri 4/20/07	Fri 4/20/07		
80		Update Website Week 14-Final	1 day?	Fri 4/27/07	Fri 4/27/07		
81		Weekly Report, Wk. 1	1 day?	Fri 1/19/07	Fri 1/19/07		
82		Weekly Report, Wk. 2	1 day?	Fri 1/26/07	Fri 1/26/07		
83		Weekly Report, Wk. 3	1 day?	Fri 2/2/07	Fri 2/2/07		
84		Weekly Report, Wk. 4	1 day?	Fri 2/9/07	Fri 2/9/07		
85		Weekly Report, Wk. 5	1 day?	Fri 2/16/07	Fri 2/16/07		
86		Weekly Report, Wk. 6	1 day?	Fri 2/23/07	Fri 2/23/07		
87		Weekly Report, Wk. 7	1 day?	Fri 3/2/07	Fri 3/2/07		
88		Weekly Report, Wk. 8	1 day?	Fri 3/16/07	Fri 3/16/07		
89		Weekly Report, Wk. 9	1 day?	Fri 3/23/07	Fri 3/23/07		
90		Weekly Report, Wk. 10	1 day?	Fri 3/30/07	Fri 3/30/07		
91		Weekly Report, Wk. 11	1 day?	Fri 4/6/07	Fri 4/6/07		
92		Weekly Report, Wk. 12	1 day?	Fri 4/13/07	Fri 4/13/07		
93		Weekly Report, Wk. 13	1 day?	Fri 4/20/07	Fri 4/20/07		
94		Weekly Report, Wk. 14-Final	1 day?	Fri 4/27/07	Fri 4/27/07		
95		Write Owner's Manual	20 days?	Mon 4/2/07	Fri 4/27/07		
96		Make sure user is properly electrically isolated from monit	1 day?	Mon 4/16/0	Mon 4/16/0		
97		Create Senior Design Day PowerPoint Presentation	10 days?	Mon 4/9/07	Fri 4/20/07		
98		Senior Design Day	1 day?	Fri 4/27/07	Fri 4/27/07		
99		Order any parts still needed	1 day?	Fri 3/2/07	Fri 3/2/07		
100		Troubleshoot complete vital signs monitor	5 days?	Mon 4/16/0	Fri 4/20/07		

8 Team Members Contributions to the Project

Throughout the semester, Team #3 met at least once a week to work on project design. All papers and presentations were group efforts. Each team member's specific work is described below.

Robert Croce

Rob's main contributions were in the areas of processing and displays. As the project began, he began looking into which microprocessors would be suitable for the specific information that had to be processed. At first, the highly popular PIC16F877 Microchip seemed like it would handle the majority of the operations in the design. As more research went into the design, it was concluded that either multiple processors or one large processor would be needed. The Blackfin Digital Signal processor was then chosen. Since then, Rob has continued to learn about this latest digital processor. He has been working on LabVIEW code, which will be used to program this processor. He has also revisited the Biosignals class to reread FIR and IIR filters, which will be used in filtering the incoming signals form the patients body. These filters, as well as the analog to digital converters, can be found in the LabVIEW Embedded Module for Analog Devices Blackfin Processors software. He also researched the display units and speech chips and has been working on sending the information to these units, as well as the initial prototype of the respiratory rate design. Rob also considered the casing of the unit. Currently, a method of constructing a case using an AutoCAD drawing is being researched.

Michael Kapinos

Mike was in charge of dealing with a few of the different features incorporated in the home vital signs monitoring system. Mike did research on the use of the USB port which allowed an easy way to be found to send the date from the microprocessor to a local health care provider. His research made it so that while using the USB portion of the device it will be easier to use a PIC microprocessor to take away some of the load that the Black fin will be carrying. Mike was also in charge of researching the power supply and rechargeable batteries. By meeting with a senior in the Electrical Engineering department he learned how to connect the power supply to the device and how to break it down so the transducers will not use too much voltage. Mike was also in charge of selected buttons that best fit with the device. These buttons needed to be easy to push down and also include Braille. Mike was in charge of selecting a digital scale that will easily be incorporated into the device. Aside from the above features Mike also wrote some of the project documents and presented a portion of the projects proposal.

Jenna Sullivan

Jenna worked mainly on the transducers and their circuitry. She is responsible for all of the research, design, and part selection of the thermometer, pulse oximeter, blood pressure, and respiratory rate (except Design 2, where Rob researched the respiratory belt) devices. In addition to this, Jenna was responsible for the Bluetooth wireless option seen in Design 3 and the Optimum Design. She created the final circuit diagram of the vital signs monitor and did much of the writing in the project reports. She also integrated

the sections of the final report into one cohesive work. Throughout the semester, Jenna focused on group communication and timeliness in completing work. And, Jenna did research into client needs and the home health care environment.

9 Conclusion

As healthcare moves out of the hospital and into the home, reliable technology for monitoring patients' health is needed. Vital signs monitors provide basic, yet important, information about a patient's physical well being. Unfortunately, many of the vital signs monitoring systems available today are very expensive and inaccessible. Most are designed for hospital use and have complicated interfaces that do not blend well with the home environment. More devices are needed that are designed specifically for home use by patients, their families, and caregivers.

The accessible home vital signs monitoring system described in this report fulfills the need for an accessible, user-friendly, home-use vital signs monitor. The simple 3-button design makes the device easy to use for all ages and abilities. To provide comprehensive health care monitoring, our device is designed to record the following six (6) vital signs: body temperature, blood oxygen saturation, heart rate, blood pressure, weight, and respiratory rate. Accessibility is addressed through the speech module, auditory and visual alarms, large LCD screens, and buttons customized with Braille or Universal Symbols. These features allow us to meet the needs of our clients with a device that is accessible to the hearing and visually impaired, those with motor skills impairment, and patients of all ages.

To create a reliable medical device, existing technologies were brought together and combined into a single functioning unit. As in the optimal design, body temperature is measured by a thermistor circuit involving a Wheatstone bridge. Blood oxygen saturation and pulse are calculated from pulse oximetry readings. An automated blood pressure system using the oscillometric method measures blood pressure. To measure respiratory rate, a thermocouple registers the changes in the temperature of air being inhaled and exhaled. This rate is analyzed by a microprocessor to determine the respiratory rate. Finally, a simple scale is used to measure weight. By keeping realistic constraints in mind throughout the design process (cost, timelines, resources), we were able to design an affordable and manufacturable device. Safety was always in consideration during the three alternative designs and the optimal design, so as to design a vital signs monitor that would be a help to our clients' health rather than a hindrance. Aside from physical safety, personal safety and privacy is ensured by the password protected website through which clients can upload their vital signs to their physicians or healthcare providers. It is from all this that our accessible home vital signs monitoring system will improve quality of life by improving the quality of care.

10 References

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+circuit+design+safety&hl=en&gl=us&ct=clnk&cd=1>.

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11 Acknowledgements

We would like to acknowledge the following people, to thank them for their support and assistance with our project:

Rehabilitation Engineering Research Center on Accessible Medical Instrumentation
RERC-AMI National Student Design Competition, Provided Funding
Dr. John Enderle, Client Contact and Advisor
Bill Pruesner, Advisor
Dave Price

12 Appendix

12.1 Updated Specifications

<u>Mechanical</u>

Weight (unit without peripheries)	<6 pounds
Size	20cm x 10cm x 20cm max., handle for transport
Button size	15mm x 20mm
Durability	Able to transported and withstand minor bumps and disturbances
Water Resistance	Recommend avoid water and spills
Anchoring/Mounting	Rubber treads on bottom of device

Electrical

Power Source	120V AC
Back-up battery	Rechargeable 9V NiCd
Display	
Height	20cm max
Width	40cm max
Illumination	Back-lit LCDs
Data Output	Standard USB port Bluetooth Wireless Transmission
Temperature Measurements	
Scale	°Fahrenheit (F)
Range	90-110°F
Accuracy	± .2°F
Response Time	10 seconds (oral)
Pulse Oximetry	
Saturation Range	94-98%
Accuracy	± 3%
Heart Rate Range	80-250bpm
Accuracy	± 3bpm
Non-invasive blood pressure (NIBP)	
Cuff Pressure Range	0-160mmHg
Measurement Time	<60 seconds
Respiratory Rate	
Range	0-60 breathes per min.
Measurement Time	30 seconds
Weight	
Scale Type	Digital
Range	TBD

Hardware and Software Parameters

Microprocessor	Analog Devices Blackfin DSP
Programming Language	LabVIEW™

Environmental

Location	Home (indoors)
Dust	Recommend preventing large amounts of dust from settling on the device
Operating Temperature	50-105°F
Storage Temperature	40-110°F

12.2 Purchase Requisitions and Quotes

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Michael Kapinos	**Total Expenses**	2,000
Ship to:	University of Connecticut	**Lab Admin only:**	
	Biomedical Engineering	**FRS #**	
	U-2247, 260 Glenbrook Road	**Student Initial Budget**	
	Storrs, CT 06269-2247	**Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
693-1241.6634.1121	Snap-in Style Pushbutton		3	$34.40	$103.20
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
Comments					
Price Quote				**Shipping**	$0.00
File Name:				**Total:**	**$103.20**

Yes or No	***Vendor Accepts Purchase Orders?***
Vendor:	**Mouser Electronics**
Address:	www.mouser.com
Phone:	
Contact Name:	

Authorization:

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Michael Kapinos	**Total Expenses**	2,000
Ship to:	University of Connecticut	**Lab Admin only:**	
	Biomedical Engineering	**FRS #**	
	U-2247, 260 Glenbrook Road	**Student Initial Budget**	
	Storrs, CT 06269-2247	**Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
EG-000138	AC to DC Power Converter		1	$29.95	$29.95
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
Comments					
Price Quote				**Shipping**	$10.47
File Name:				**Total:**	**$40.42**

Yes or No	***Vendor Accepts Purchase Orders?***	
Vendor:	**Shop.com**	
Address:		
	www.shop.com	**Authorization:**
Phone:	**1-866-746-7005**	
Contact Name:		

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Michael Kapinos	**Total Expenses**	2,000
Ship to:	University of Connecticut Biomedical Engineering U-2247, 260 Glenbrook Road Storrs, CT 06269-2247	**Lab Admin only:** **FRS #** **Student Initial Budget** **Student Current Budget** **Project Sponsor**	
Attn:			
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
ALL-RB-9V-S250-SP01	9V Rechargable Battery		3	$5.88	$17.64
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote File Name:		**Shipping**	$6.49
		Total:	**$24.13**

Yes or No	***Vendor Accepts Purchase Orders?***
Vendor:	**Open Tip**
Address:	www.opentip.com
Phone:	**1-888-882-8232**
Contact Name:	

Authorization: ______________________

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Michael Kapinos	**Total Expenses**	2,000
Ship to:	University of Connecticut Biomedical Engineering U-2247, 260 Glenbrook Road Storrs, CT 06269-2247	**Lab Admin only:** **FRS #** **Student Initial Budget** **Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
SC-200	Homemedics Digital Bathroom Scale		1	$19.95	$19.95
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	$0.00
File Name:		**Total:**	**$19.95**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Whole Sale Point**		
Address:	www.wholesalepoint.com	**Authorization:**	
Phone:	**1-800-986-0525**		
Contact Name:			

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3	
Student Name:	Michael Kapinos	**Total Expenses**	2,000	
Ship to:	University of Connecticut	**Lab Admin only:**		
	Biomedical Engineering	**FRS #**		
	U-2247, 260 Glenbrook Road	**Student Initial Budget**		
	Storrs, CT 06269-2247	**Student Current Budget**		
Attn:		**Project Sponsor**		
Project Name:	Accessible Home Vital Signs Monitor			

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
693-1241.6634.1121	PIC Microprocessor		1	$5.84	$5.84
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote File Name:		**Shipping**	$0.00
		Total:	**$5.84**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Microchip Direct**		
Address:	www.microchipdirect.com	**Authorization:**	
Phone:			
Contact Name:			

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Michael Kapinos	**Total Expenses**	2,000
Ship to:	University of Connecticut	**Lab Admin only:**	
	Biomedical Engineering	**FRS #**	
	U-2247, 260 Glenbrook Road	**Student Initial Budget**	
	Storrs, CT 06269-2247	**Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
568-1091-5-ND	Philips USB Chip (PDIUSBD12)		1	$3.49	$3.49
497-1382-5-ND	Linear Voltage Regulator		1	$3.11	$3.11
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
Comments					
Price Quote				**Shipping**	$6.41
File Name:				**Total:**	**$13.01**

Yes or No	***Vendor Accepts Purchase Orders?***
Vendor:	**Digi-Key Corporation**
Address:	www.digi-key.com
	701 Brooks Avenue South
	Thief Rivers Falls, MN 56701
Phone:	**1-800-433-4539**
Contact Name:	

Authorization:

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Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3	
Student Name:	Jenna Sullivan	**Total Expenses**	2,000	
Ship to:	University of Connecticut	**Lab Admin only:**		
	Biomedical Engineering	**FRS #**		
	U-2247, 260 Glenbrook Road	**Student Initial Budget**		
	Storrs, CT 06269-2247	**Student Current Budget**		
Attn:		**Project Sponsor**		
Project Name:	Accessible Home Vital Signs Monitor			

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
	CVS Arm Cuff Large		1	$9.99	$9.99
	Vicks Speed Read Digital Thermometer V911		1	$11.99	$11.99
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	$0.00
File Name:		**Total:**	**$21.98**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**CVS Pharmacy**		
Address:	**632 Middle Turnpike**		
	Mansfield, CT 06268	**Authorization:**	
Phone:	**860-487-2034**		
Contact Name:			

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Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Jenna Sullivan	**Total Expenses**	2,000
Ship to:	University of Connecticut	**Lab Admin only:**	
	Biomedical Engineering	**FRS #**	
	U-2247, 260 Glenbrook Road	**Student Initial Budget**	
	Storrs, CT 06269-2247	**Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

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Catalog #	Description	Unit	QTY	Unit Price	Amount
	E161-11-060, CTS Single Head Pump		1	$48.00	$48.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	$9.18
File Name:		**Total:**	**$57.18**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Hargraves Advanced Fluidic Solutions**		
Address:	**127 Speedway Drive**		
	Mooresville, NC 28117 USA	**Authorization:**	
Phone:	**704-662-3500**		
Contact Name:			

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Jenna Sullivan	**Total Expenses**	2,000
Ship to:	University of Connecticut Biomedical Engineering U-2247, 260 Glenbrook Road Storrs, CT 06269-2247	**Lab Admin only:** **FRS #** **Student Initial Budget** **Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
	MPX2200AP-ND Sensor		1	$12.78	$12.78
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	$11.41
File Name:		**Total:**	**$24.19**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Digikey**		
Address:	**701 Brooks Avenue South** **Thief Rivers Falls, MN 56701**	**Authorization:**	
Phone:	**800-433-4539**		
Contact Name:			

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Robert Croce	**Total Expenses**	2,000
Ship to:	University of Connecticut	**Lab Admin only:**	
	Biomedical Engineering	**FRS #**	
	U-2247, 260 Glenbrook Road	**Student Initial Budget**	
	Storrs, CT 06269-2247	**Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
CFAH1602L	122mm * 44mm PCB Size, Green LED Backlight		6	$27.37	$164.22
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	$12.75
File Name:		**Total:**	**$176.97**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Crystalfontz**		
Address:	www.crystalfontz.com	**Authorization:**	
Phone:	**1-888-206-9720**		
Contact Name:			

PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

Date:	November 25, 2006	**Team #**	3
Student Name:	Robert Croce	**Total Expenses**	2,000
Ship to:	University of Connecticut Biomedical Engineering U-2247, 260 Glenbrook Road Storrs, CT 06269-2247	**Lab Admin only:** **FRS #** **Student Initial Budget** **Student Current Budget**	
Attn:		**Project Sponsor**	
Project Name:	Accessible Home Vital Signs Monitor		

ONLY ONE COMPANY PER REQUISITION

Catalog #	Description	Unit	QTY	Unit Price	Amount
ADSP-BF537BBCZ5A	Blackfin BF535 Processor		1	$23.63	$23.63
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00

Comments

Price Quote		**Shipping**	
File Name:		**Total:**	**$23.63**
Yes or No	***Vendor Accepts Purchase Orders?***		
Vendor:	**Crystalfontz**		
Address:	www.analog.com	**Authorization:**	
Phone:	**1-800-262-5643**		
Contact Name:			